UNITED STATES DEPARTMENT OF AGRICULTURE

BULLETIN No. 440

Contribution from the Forest Service
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Washington, D. C. PROFESSIONAL PAPER March 8, 1917

LUMBERING IN THE SUGAR AND YELLOW PINE REGION OF CALIFORNIA.

By Swift Berry, *Forest Examiner*.

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PART I. INTRODUCTION.

THE REGION.

The sugar and yellow pine region of California extends from the northern boundary of the State southward the entire length of the Sierra Nevada, chiefly west of the summit, and along the Coast Range to Lake County. In this bulletin the region is extended to include the commercial forests of California outside of the coast redwood region, thus taking in the practically pure stands of yellow and Jeffrey pine on the east slope of the Sierras, from the Warner Mountains southward.

The region has three main topographic divisions—the Northern Coast Range, the Sierras, and the east slope of the Sierras and Cascades. The Northern Coast Range begins in Lake County and extends northward along the Trinity and Klamath Mountains to the Siskiyous. This is a region of steep slopes, much broken by

secondary ones. The main streams are at low elevations, and the main ridges are narrow but continuous at almost uniform elevations for long distances. The main characteristic of the second division, the Sierras, is deep canyons or stream courses extending in a westerly direction. Between these main streams are high timbered plateaus and ridges. Toward the north the elevations are lower. On the whole the slopes are more uniform and continuous and not so steep as those in the Coast Range. The surface is, however, more often rocky. While the rock of the Coast Range is sedimentary, that of the Sierras is chiefly granite. The third division, east of the Sierras, extends from Truckee on the south to Klamath Lake on the north, and is typically a region of yellow pine timber, fairly easy slopes, and smooth surfaces. There are many broad valleys and level tracts. The soil and rock are volcanic. Although much of this country is actually on the headwaters of streams flowing westward into the Sacramento, it is sufficiently well characterized by the term "East Slope."

The early lumbering operations in California were in the southern part of the East Slope and, on a smaller scale, in the Southern Sierras. At the present time operations are distributed along the entire western border of the Sierras, and a heavy output comes from both the northern and southern ends of the East Slope division. As yet lumbering in the Northern Coast Range is on a small scale, and the timber resources of that region await future development, as do extensive areas of virgin timber lands in the Sierras and on the East Slope.

Because there are no lumbering operations of any size in the Coast Range south of Siskiyou County and none south of the Tehachapis, the scope of this bulletin is practically confined to the Sierras and the East Slope. The descriptions of logging systems and equipment are confined to those actually in use. No attempt is made to contrast methods or efficiency with other regions.

THE FOREST.

The total merchantable stand of saw timber in California, exclusive of the redwood belt, has been estimated at 263,600,000,000 feet, board measure, of which 131,200,000,000 feet is privately owned and 132,400,000,000 feet is the property of the Government. Of the latter amount, 115,800,000,000 feet is in the National Forests and the rest in national parks and Indian reservations or upon the public domain. The private and National Forest timber taken together, a total of 247,000,000,000 feet, board measure, is composed of the principal forest species in about the following proportion: Sugar pine, 15 per cent; western yellow pine, 38 per cent; Douglas fir, 19 per cent; white fir, 14 per cent; incense cedar, 3 per cent; California red fir, 4

per cent; lodgepole pine, 2 per cent; big tree, 2 per cent; other species, 3 per cent.

The region is essentially one of mixed stands. The four typical species are sugar pine (*Pinus lambertiana*), western yellow pine (*Pinus ponderosa*), white fir (*Abies concolor*), and incense cedar (*Libocedrus decurrens*). All four are found throughout the region, though sugar pine and incense cedar are infrequent in the pine stands on the eastern slope of the Sierras. In these stands and at high elevations yellow pine is frequently mixed with or supplanted by Jeffrey pine (*Pinus jeffreyi*). No difference appears to be made commercially between the lumber of these two species, which is known to the trade as white pine or California white pine. Douglas fir (*Pseudotsuga taxifolia*) forms the bulk of the stand in the Northern Coast Ranges; and on the western slope of the Sierras it extends south to Fresno County. In the Northern Coast Ranges this species forms nearly pure stands, but all exploitation of it in California is in connection with other timber species. California red fir (*Abies magnifica*) also forms pure stands, but at such elevations that it is seldom reached by lumbering operations. Lodgepole pine (*Pinus contorta*) is little exploited on account of the inaccessible locations of its stands and of its relatively poor qualities. The stand of big trees (*Sequoia washingtoniana*) timber is confined to the Southern Sierras, where it occurs in large groups or groves. This species is logged, incidentally with other species, for the manufacture of lumber by one large and one small concern.

The stands now merchantable vary in volume from an average of 11,000 feet, board measure, per acre in the pine and white fir stands east of the Sierras to an average of 50,000 feet per acre in the heart of the sugar-pine belt. Other representative stands average 25,000 feet per acre in the Northern Coast Ranges; 23,000 feet on the upper Sacramento; 27,000 feet on the lower Feather River; 25,000 feet on the Consumnes River; 30,000 feet on the Stanislaus River; and 25,000 feet on the Kings River. The maximum stand per acre on record is 200,000 feet, of which approximately 75 per cent is sugar pine. Good quarter sections run as high as 70,000 feet per acre. The majority of the present lumbering operations are located in stands averaging from 18,000 to 40,000 feet per acre.

The timber ranges in size from an average breasthigh diameter of 28 inches to an average of 50 inches for trees over 12 inches in diameter. Individual sugar-pine trees have been found with a breasthigh diameter of 120 inches. The height ranges from 4-log trees in the yellow and Jeffrey pine stands to 13-log trees in the best sugar and yellow pine. A 16-foot length is regarded as the standard log.

The following average figures, which were obtained from the cruising measurements on two large timber sale areas in the Sierras, show

the relation between trees over 12 inches in diameter breasthigh of the four leading species, in very good sugar and yellow pine stands:

	Area I.		Area II.	
	Average diameter.	Average number logs.	Average diameter.	Average number logs.
	Inches.		*Inches.*	
Sugar pine	42	9	46	9
Yellow pine	38	8-9	38	8
White fir	33	8	34	8
Incense cedar	31	7	32	6

The average number of 16-foot logs per 1,000 feet, board measure, varies from between three and four in the poor stands to between one and a half and two in the best. The average for the region is between two and three logs per 1,000.

TYPES OF OPERATIONS.

The sawmill plants cutting pine lumber in California range from the small circular mills which produce not more than 200,000 feet per year to one with two large double band mills with a combined annual output of 90,000,000 feet. The small mills, either steam or water power, are supplied with logs by means of horses or oxen, and operate only when there is a local demand for lumber. The large mills run two shifts daily and are furnished with logs by logging railroads and modern steam logging contrivances or big wheels. Between these two extremes are operations of all grades and sizes, the principal intermediate classes being the circular mills producing from 25,000 to 40,000 feet daily for the general market and the single band mills. Most of the large circular mills are supplied by horse logging with trucks or by big wheels or chutes. The single band mills are usually supplied by logging railroads and logging donkeys; a few use horse trucks or traction engines and trucks.

Logging and lumbering operations may be classified according to the size of the mills, because each mill and the logging equipment which supplies it are commonly owned by the same person or corporation. Since none of the mills are located on tidewater, or drivable streams, there are no log markets nor logging companies such as exist in the Pacific Northwest. The 600,000,000 feet of lumber produced in the California pine region annually is manufactured by 15 double-band mills, 14 single-band mills, 25 large circular mills, and a host of small circular mills. Each of these implies a separate lumbering operation, except in the case of one concern operating two double-band mills and another having one single band and one large circular, each with a resaw.

Widely as the operations vary in type, they are alike, with the exception of one new operation, in that logging is done only during the summer months. It may begin during the latter half of April or the first part of May and continue until November or the beginning of December, depending upon the altitude and latitude. The average operation is under way about May 10 and continues until the latter part of November, thus having a season of from 156 to 165 working-days. Sawing begins shortly after the work in the woods and ordinarily continues for from one to four weeks longer. Both logging and milling are customarily shut down for the winter by Christmas or before.

LABOR.

Since most of the labor is employed for less than seven months each year, it is inclined to be unstable. There are two classes—one, to which belong most of the men in the skilled and better-paid positions, winters on the ranches and in the towns of central California, frequently returning to the same operation season after season; the other is purely transient and works on one job from a few days to one season and then moves on to the next. The mill crews are usually much less transient than the woods force.

The labor problem is yearly becoming more difficult, and the proportion of foreign labor is increasing. The bulk of the woods work is now done by American-born workmen. The more tedious work—bucking, swamping, and woodcutting—is largely done by southern Europeans. This is also true of railroad construction, though some companies have Irish and American crews. In some localities Indians perform the cheaper woods work and Mexicans are employed in railroad grading. In the sawmills American labor prevails in the more important positions and in handling machinery. Unskilled labor in the mill and nearly all lumber handlers are southern Europeans. Frequently entire yard crews, with the exception of the foreman, are composed of Italians. Labor in box factories and finishing plants is usually American born and, especially in the box factories, is made up of young men and boys.

Labor for logging camps is usually secured by hiring either at the plant or in the nearest city or large town. In the spring the higher grade employees make application to the superintendent, some even being hired by letter. Many of the other men do the same, but it is frequently necessary for the logging superintendent to visit the nearest city and engage men, paying their way to the works and guaranteeing their unpaid board bills. Later on in the summer, when the men become restless and begin to leave, it is often necessary to secure men from employment agencies, which entails paying the fares to the plant. The men are usually hired by the day or the month. Labor

is often employed on contract in felling, limbing, and bucking logs, and in piling lumber. These activities can be easily supervised and require no capital on the part of the contractor. The standard working-day is 10 hours. In sawmills and yards the full time is put in at labor, but in the logging and railroad camps the crews usually return from work on company time, which often means that not over $9\frac{1}{4}$ or $9\frac{1}{2}$ hours are put in at work. A State law of California provides that boys under 18 years of age can not be worked longer than 8 hours daily.

A workmen's compensation act went into effect in California on January 1, 1914. This act renders the employer liable for compensation for all personal injuries sustained by employees during the course of employment, except in the case of injury due to intoxication or willful misconduct on the part of the employee injured. It provides for the payment of medical and hospital fees for a period of 90 days after injury, for disability indemnities, and for benefits to dependents in case of death, all payments to be made as directed by the Industrial Accident Commission. Another feature of the act is the provision empowering the State Accident Commission to conduct a department for insuring operators against the liabilities. One effect of this act will undoubtedly be an increase in the amount of labor employed on contract.

Medical attention and hospital treatment have been and are yet furnished by most companies at their own hospitals, which are supported by deducting $1 monthly from the wage of each employee. Smaller operators frequently contract with local physicians to care for their men under the same arrangement. The compensation act provides that no deduction may be made in wages to carry out its provisions, but the present hospital charges are apparently made on the basis of care during sickness.

Lumbering wages are paid at a stated sum per day without board or at a stated amount per month and board. The former is customary as far south as Plumas County, and the latter throughout the rest of the region, except at sawmills and yards located in towns. The first system operates in the employer's favor in the case of loss of time through sickness or inclement weather.

In the lists of representative wages for the season of 1913, which follow in Table 1, "North" refers to the territory north of Plumas County, and "Central" to the country south of this point. "East" refers to the region on the east slope of the Sierras about Sierra Valley. The two columns "A" and "B" under each represent different localities or operations.

TABLE 1.—*Wages paid in the sugar and yellow pine lumbering region of California.*

	North (without board).		Central (with board).		East (with board).
	A.	B.	A.	B.	
Railroad work.	*Per day.*	*Per day.*	*Per month.*	*Per month.*	*Per month.*
Grading foreman	$5.00	$4.00	$100.00	$80.00	....
Trestle foreman	4.50	....	....	....	....
Teaming foreman	3.50	....	....	....	....
Powder man	3.00	3.00	45.00	45.00	....
Driller	2.50	2.50	40.00	40.00	....
Teamster	2.50	....	....	40.00	....
Muckers	2.25	2.25	35.00	35.00	....
Section foreman	3.50	3.00	75.00	70.00	....
Section man	2.25	2.25	40.00	35.00	....
Steam logging crew.					
Undercutter	....	....	75.00	....	....
Faller	3.50	3.00	65.00	65.00	$65.00
Bucker	3.00	3.00	50.00	50.00	60.00
Limber	2.75	2.50	50.00	55.00	50.00
Saw filer	4.00	3.50	65.00	....	....
Hook tender	4.50	4.25	100.00	100.00	100.00
Chaser	3.25	....	....	....	....
Frogger	....	2.75	65.00	60.00	70.00
Rigger	2.75	3.00	60.00	50.00	60.00
Swamper	2.75	2.50	60.00	50.00	50.00
Choker-hole digger	2.50	2.50	50.00	....	50.00
Whistlepunk	2.25	2.25	40.00	....	40.00
Frog shoveler	....	2.25	40.00	40.00	50.00
Lookout	....	....	....	50.00	....
Engineer	3.25	3.25	60.00	65.00	70.00
Fireman	2.75	2.50	40.00	45.00	50.00
Loader	3.25	3.00	60.00	70.00	75.00
Second loader	2.75	2.75	....	50.00	65.00
Winchman	....	....	45.00	....	....
Spool tender	2.75	2.50	....	50.00	50.00
Woodbuck	....	....	40.00	40.00	....
Wood teamster	....	2.50	50.00	....	....
Waterbuck	....	....	45.00	40.00	....
Night watch	....	....	45.00	50.00	....
Chute lineman	....	....	90.00	80.00	90.00
Bellhop	....	....	55.00	50.00	50.00
Chute greaser	....	....	45.00	40.00	40.00
Chute engineer	....	....	80.00	60.00	70.00
Horse-logging crew.					*Per day.*
Wheel teamster	3.25	2.75	....	....	2.75
Bunch teamster	3.25	3.00	....	....	2.50
Hooker	2.75	2.50	....	....	....
Gopher	2.50	2.30	....	....	....
Loader	3.00	2.70	....	....	2.25
Swamper	2.25	2.25	....	....	1.75
Roadman	2.25	2.25	....	....	1.75
Truck teamster	3.75	4.50	....	....	4.00
Skidding teamster	....	3.25	....	....	2.50
Train crew.					
Engineer	5.00	4.00	85.00	....	....
Fireman	3.50	3.00	50.00	....	....
Conductor	4.00	3.75	65.00	....	....
Brakeman	3.10	3.00	50.00	....	....

	Average for region (with board).
Miscellaneous.	*Per month.*
Donkey doctor	$75.00–$80.00
Storekeeper	75.00
Timekeeper	70.00– 85.00
Scaler	60.00– 70.00
Cook	100.00
Second cook	60.00
Cookhouse helpers	45.00

TABLE 1.—*Wages paid in the sugar and yellow pine lumbering region of California*—Con.

	Large mills.		Small mills.	
Sawmill crews.	*Per day.*	*Per month.*	*Per day.*	*Per month.*
Foreman		$150.00–$175.00		$125.00–150.00
Pondman		50.00– 60.00	$3.00–$3.25	60.00
Scaler	$2.50–$3.00	50.00		
Winchman	2.50	45.00	3.00	60.00
Deckman	2.50– 2.75	45.00– 50.00		45.00
Setter	3.25– 3.50	65.00– 75.00	3.25– 3.75	70.00– 75.00
First dogger	3.25	65.00	2.75– 3.50	45.00– 65.00
Second dogger	3.00	60.00		
Band sawyer	6.00– 7.00		5.00	
Circular sawyer	5.00		4.00– 4.50	
Offbearer	2.50– 3.00	45.00– 60.00	3.00	50.00
Pointer	2.25– 2.75	40.00– 50.00		
Edgerman	3.75	75.00	3.50– 3.75	70.00–75.00
Rear edgerman	2.50	45.00		
Slashman	2.25– 2.50	40.00– 45.00		
Trimmer	3.25		3.00	65.00
Trimmer helper	2.50	45.00	2.50	45.00
Laborer	2.25– 2.50	40.00– 45.00	2.50	45.00
Slabman			2.50	45.00
Cutoff man			2.50– 2.75	45.00– 50.00
Engineer		90.00– 110.00	3.75– 4.75	80.00– 100.00
Fireman	3.00– 3.25	60.00– 65.00	3.25	65.00
Oiler	3.25	65.00		
Millwright	5.00			75.00
Second millwright	3.50			
Filer	7.00– 8.00		3.75– 5.00	
Watchman	2.75	55.00	2.75	50.00
Grader	3.75– 4.00		3.75	
Sorter	2.50		2.50	45.00
Car pusher	2.50		2.50	45.00
Piler	2.50		2.50	45.00

NOTE.—Board is furnished in addition where the wages are monthly; it is not where they are daily.

CAMPS.

TYPES OF CAMPS.

Both the size and location of logging camps depend upon the type of the operation. In most horse logging operations the camps for the loggers are at the sawmill; but in railroad and traction operations they are placed in the woods along the track and as near the logging as possible. To obviate the necessity of long walks to work, large logging camps must be moved at intervals of from one to three seasons. For this reason the portable camp is supplanting the old style permanent type which was torn down or abandoned at every move. The old type consisted of large bunk houses, with double tiers of bunks down the sides. The initial cost of such camps is low, but they can not be moved or kept free from vermin, and the men dislike them.

The portable camp is practically uniform throughout the region. The sleeping quarters are frame cabins 10 by 18 feet or 9 by 22 feet, the former being the usual type on standard gauge operations and the latter on narrow gauge. The sides of these cabins are ordinarily 7 or 7½ feet and the roof half pitch. Low-grade lumber is used in their construction. The walls are battened and the roofs double-boarded or covered with tar paper. Two skid timbers about 8 by 10 inches are placed lengthwise under each cabin to serve as a foundation and to facilitate moving. Cabins of this kind contain about

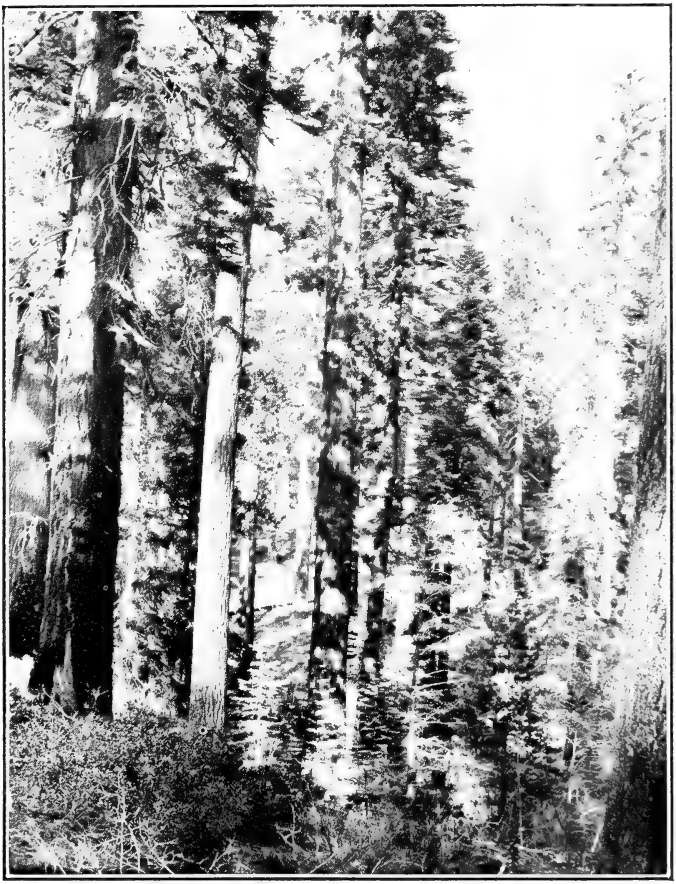

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FIG. 1.—EXCELLENT VIRGIN STAND OF SUGAR AND YELLOW PINE IN THE SIERRA NEVADAS OF CALIFORNIA.

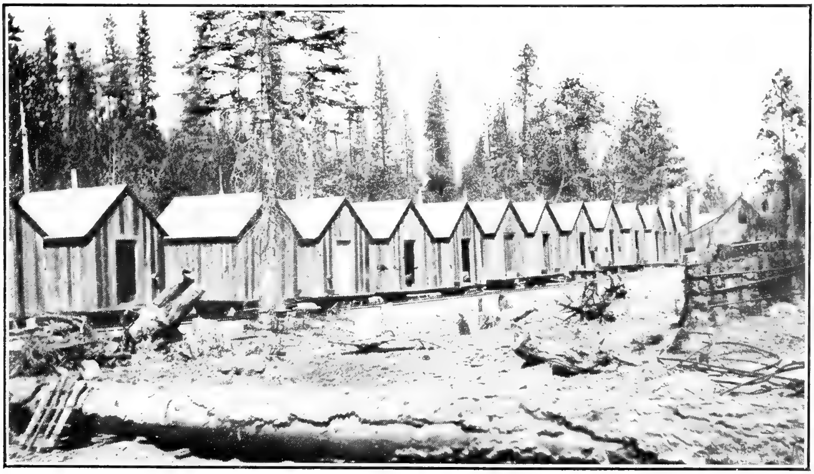

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FIG. 2.—TYPICAL PORTABLE LOGGING CAMP ON A CALIFORNIA PINE DONKEY LOGGING OPERATION.

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FELLING A LARGE YELLOW PINE TREE IN A MIXED STAND OF SUGAR AND YELLOW PINE ON A NATIONAL FOREST TIMBER SALE AREA.

1,600 feet of lumber and cost from $60 to $70 each. If double-boarded throughout, the cost is probably from $90 to $100. Each accommodates four men in single bunks, or preferably in steel cots, and provides about 500 cubic feet of air space per man. There is also room for a stove and usually a small table. In some camps only three men are assigned to a cabin, which leaves room for a large table. The use of dining cars and bunk cars is limited to a few camps, but will probably increase. For railroad construction camps and camps at a distance from the railroad, and sometimes for stables and dining rooms at portable camps, tents are frequently used. They can be taken down and stored during the winter. If cared for, a good tent should last three or four seasons.

When it is desired to move to a new site, the cabins are loaded on flat cars by means of donkey engines. The cookhouse, stable, and shop are either abandoned or torn down and the lumber utilized again. Ordinarily an average sized camp can be moved in one day. The cabins should last for at least 8 or 10 seasons, depending upon the number of moves. Some operators place several cabins end to end to form a portable cookhouse and dining room.

Steam donkey logging camps vary in size from those with two yarders to those with five. Each large operation usually has at least two camps with two or three yarders each if the logging is good, or four or five yarders each if logging is difficult or if the mill is operating double shift. The first would have from 60 to 80 men and would require about 20 cabins, costing $70 each; a frame cookhouse and dining room 20 by 60 feet, costing $350; one stable, costing $150; and a blacksmith shop, costing $50; making a total cost for buildings of about $1,950. The larger camp would contain from 125 to 150 men and have 45 cabins, a cookhouse costing $450, a stable costing $250, and a blacksmith shop costing $100; total, $3,950.

Bedding is not furnished and mattresses but seldom, though each man is usually permitted to take enough hay for a bed. One company furnishes mattresses, operates a laundry, and provides hot and shower baths in its camps, for all of which each man is charged $2 per month. Small commissaries are provided in most camps and are tended by the foreman and timekeeper.

At small sawmills and mills located in the timber the men are housed in frame cabins larger than those used in the logging camps, though similar in construction. A common dining room is provided, and there may be a few cottages for families. In sawmill towns large boarding houses are usually maintained for the single men and cottages are provided for renting to the married employees.

A modern mill town recently constructed in connection with a double-band mill is reported to have cost as follows:

Mess house	$3,700
Bunk house	2,200
Sewer system	3,400
Water system	3,200
Dwellings	18,000
Total	30,500

BOARDING.

The cost to the company of boarding men usually ranges from $18 to $22 per month, a figure of $20 being the average at mill camps and the one commonly used by most companies in figuring costs. At camps where the employees are required to pay board the rates range from $20 a month to 25 cents per meal, the equivalent of $22.50 per month.

FACTORS AFFECTING THE CUT.

CULL.

Cull is the discount from the gross scale because of rot, breakage, or defects in form. The figures available are based principally upon the judgment of competent timber estimators and scalers, not on actual measurements. Sugar and yellow pine are the least defective and are discounted from 0 to 4 per cent, and sometimes 5 per cent. Douglas fir is quite defective in many parts of the region, particularly in the Coast Range, where the cull ranges from 10 to 25 per cent. White fir has from 10 to 25 per cent cull throughout the region, and red fir stands have about the same amount. Because of its peckiness, incense cedar is the most defective and is culled from 15 to 40 per cent. Measurements covering an area of 360 acres on the Shasta Forest gave the following losses through defects and breakage: Sugar pine, 14.5 per cent; yellow pine, 10 per cent; Douglas fir, 23.5 per cent; white fir, 15 per cent; and incense cedar, 17 per cent.

UTILIZATION.

In the private operations, which make up the bulk of the logging in this region, all of the timber is cut and removed which is considered merchantable by the operator. Stumps are cut from 16 to 36 inches in height, the average for most operations being from 24 to 28 inches. Tops are utilized to limits of from 8 or 10 inches in smooth pine to 14 or 16 inches in rough timber, the average being between 10 and 12 inches for pine and about 12 or 13 inches for fir and cedar. The smallest trees cut are about 14 or 15 inches inside the bark on the stump for pine and 15 or 16 inches for fir and cedar. Some concerns log all trees down to these limits, while others take only the pine and the best and most accessible of the fir and cedar. This difference in policy is usually based on different logging and

market conditions. Some operators cut the best white fir trees into logs and the remainder, including tops, into engine wood or pulp wood. An operator whose utilization is of the best type cuts pine down to a 15-inch and fir to a 16-inch diameter on the stump, stumps being cut from 24 to 28 inches high. He cuts smooth pine tops down to 8 inches, smooth fir to 10 inches, and rough tops to 12 and 14 inches. On ordinary logs he allows 4 inches for trimming; and on logs over 4 feet in diameter, 6 inches. He cuts the area clean.

The minimum log length is usually 12 feet, though on several operations valuable pine logs are taken down to 10 feet. Logs of poor quality are left in the woods if 50 per cent defective, and often if only 40 per cent defective; but, on the other hand, many firms log pine butts or clear logs which are not 25 per cent sound.

The utilization on National Forest timber sale areas is commonly more intensive. Timber sale contracts provide that stumps be cut not exceeding 18 inches in height and that tops be utilized down to 8 or 10 inches when smooth. The minimum log length is generally 10 feet, though in some instances 8 feet is specified for sugar and yellow pine. Pine logs $33\frac{1}{3}$ per cent and fir logs 50 per cent sound are considered merchantable. The young growing timber, from 20 to 30 per cent of the volume of the stand above 12 inches in diameter, remains uncut after logging.

In ordinary sawing practice the shortest board made is 10 feet and the narrowest width is 4 inches. However, the mills that have box or door factories resaw slabs to obtain suitable short pieces. Clear edgings are utilized for lath and car strips. Band saws commonly cut two-sixteenth inch or three-sixteenth inch kerf; solid tooth circular saws, four-sixteenth inch; and inserted tooth circular saws, five-sixteenth inch. Most of the clear pine lumber is cut in 1, $1\frac{1}{2}$, and 2 inch stock, and an extra thickness of from one-sixteenth to one-eighth inch is allowed on each board for shrinkage. Shop lumber is $1\frac{1}{2}$ and 2 inches in thickness, the $1\frac{1}{2}$-inch stock being sawed $1\frac{10}{16}$ or $1\frac{11}{16}$ inches thick in coarse-grained timber. Most box lumber is sawed $1\frac{1}{2}$ inches thick, though both 1-inch and 2-inch box is cut. The allowance for shrinkage is the same as in shop. Common lumber is cut in inch stuff, one-eighth inch full. In addition an extra width of from one-eighth to one-half inch is allowed on each board to provide for shrinkage. Fir lumber is usually cut without extra allowance in thickness or width.

OVERRUN.[1]

With average timber and a normal lumber product, the overrun at a mill employing an inserted tooth circular saw is negligible if not lacking. A solid tooth circular saw does a trifle better, showing a possible average overrun of 2 or 3 per cent. The figures obtained at a number of efficient band mills range from 5 to 8 per cent, the most common being 6 per cent or a fraction over. A short mill tally at a band mill sawing pine timber from a National Forest sale in the southern Sierras showed an overrun of 5 per cent.

A mill tally of 4,190 logs made during the summer of 1914 at a representative single band mill in the northern Sierras gave the following average overrun of the decimal C scale: Sugar pine, 7 per cent; yellow pine, 6.9 per cent; Douglas fir, 10.3 per cent; white fir, 2.5 per cent; incense cedar, 15.6 per cent. These percentages are perhaps slightly above the average on account of the manufacture of sawed ties from many top logs. A second tally of 4,890 logs at another single band mill during 1914 gave the following overrun: Sugar pine, 2.6 per cent; yellow pine, 0.7 per cent; Douglas fir, 8.1 per cent; white fir, 1.1 per cent; incense cedar, 16.6 per cent. Most of the overrun occurs in the logs of poorer quality.

TIMBER QUALITY.

The proportion of the various grades produced depends not only upon the quality of the timber but also upon the efficiency of the operation, the size of the mill, and the facilities for marketing lumber. Inefficient operations do not cut as high a proportion of the better grades as efficient ones. Small mills without a marketing organization do not take as much care in separating grades, and frequently put all lower grades into box.

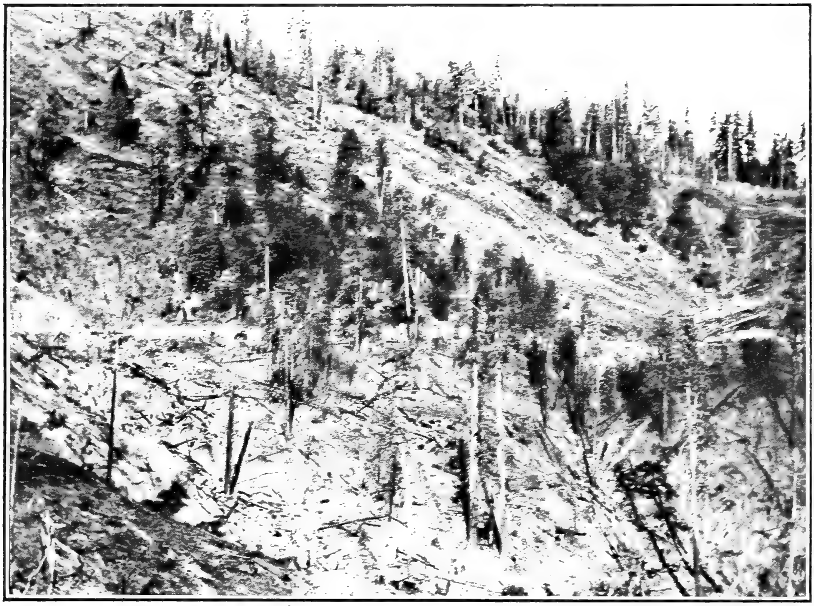
In speaking of the quality of a tract of timber it is customary to say that it will produce a certain per cent of uppers, meaning No. 2 shop and better. The poorer yellow and Jeffrey pine stands in eastern California produce about 20 per cent uppers; better stands produce from 25 to 30 per cent. Normal mixed stands of sugar pine, yellow pine, Douglas fir, white fir, and incense cedar produce from 25 to 31 per cent. In sugar and yellow pine stands the pine commonly cuts from 32 to 45 per cent uppers, yellow pine alone from 30 to 45 per cent, and sugar pine from 35 to 55 per cent.

A comparison of the lumber grades produced from sugar and yellow pine may be made from Table 2, which shows the results of two mill tallies made by the Forest Service during the season of 1914. The first of these was for 2,230 logs at a single-band mill in the southern part of the Shasta National Forest, and the second for 2,490 logs

[1] This information on mill overrun of log scale is derived from a comparison of the figures of scalers and tallymen at several representative mills. The log scale is commonly made by the Spalding rule, which is somewhat similar to the decimal C rule used on National Forest timber sales. Overrun is greater in small or very large logs; less with saws of heavy kerf, and greater when thick planks or timbers are sawed.

F–95331

FIG. 1.—LIMBING AND BUCKING TIMBER ON A NATIONAL FOREST TIMBER SALE IN THE SIERRA NEVADAS.



F–15945–A

FIG. 2.—LOGGED-OVER STAND OF SUGAR AND YELLOW PINE ON PRIVATE LAND.

at a single-band mill in the western part of the Plumas National Forest.

TABLE 2.—*Comparison of the lumber grades produced from sugar and yellow pine, showing the results of two mill tallies.*

Grades.	Mill tally No. 1.		Mill tally No. 2.	
	Sugar pine.	Yellow pine.	Sugar pine.	Yellow pine.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*
Nos. 1 and 2 clear	8.3	8.8	9.4	7.5
No. 3 clear	3.8	4.1	3.3	3.6
C select	.8	.6	.1	.2
Australian	.5	2.4	.2	1.1
No. 1 shop	7.2	8.3	11.9	12.2
No. 2 shop	10.9	13.8	14.2	14.1
No. 3 shop	5.8	4.4	6.2	6.2
Nos. 1 and 2 common	31.3	31.2	41.9	36.5
Box	30.0	25.6	12.5	18.5
No. 3 common	1.4	.8	.2	.1

PART II. LOGGING.

The term "logging" as commonly used covers all the work of handling logs from the standing timber to the sawmill. It is divided, by custom, into several steps. In the discussion which follows, each step is treated separately in the order in which it occurs in logging. The object is to give the various methods of handling each step in such a manner that they may be compared, and, further, to give approximate outputs and costs for different methods under given conditions as an aid in estimating the cost of logging in going or prospective operations.

The cost of delivering logs at the mills in this region, including railroad construction, but exclusive of depreciation on equipment, overhead expenses, and stumpage, range from $4 to $6.25 per 1,000 feet, log scale. Where the railroad hauls are medium and involve an operating expense of not more than $1 per 1,000, the cost in the easy stands is from $4 to $4.75 per 1,000. The cost in most operations is between $4.75 and $5.50 per 1,000. Difficult logging conditions and railroad haul or less efficient methods may raise the cost to from $5.50 to $6.25 per 1,000.

PREPARING LOGS FOR TRANSPORT.

Preparing logs for transport is usually spoken of as felling and bucking, though it includes limbing as well, and sometimes peeling. Felling, limbing, and bucking are commonly considered as a single step. Each felling crew, with the requisite number of limbers and buckers, is a separate unit.

EQUIPMENT.

Each set of "fallers" requires two felling saws, one for use while the other is being filed. The common length is 8 feet, though it is usually necessary to have one or two extra 10-foot saws on the job

for the larger trees. Each bucker should have two saws, and there must be some extras in the filing shack. The ordinary length of bucking saws is 7½ feet. Both kinds of saws are commonly 12-gauge on the edge and 17 gauge on the back. The bucking saw has a wider blade than the felling type and may have slightly shorter teeth. The net price at San Francisco of the best quality saws is from 72 cents to 75 cents per foot. Detachable wooden handles are used, which cost about 65 cents per pair for the reversible Pacific coast type and 35 cents per pair for the common type.

Each "faller" carries a felling ax, and each bucker and limber has a swamping ax. All axes are double bit. Felling axes vary in weight from 3½ to 4½ pounds, and the net price is from $9 to $10 per dozen for the best quality. Swamping axes are preferred about one-half pound heavier, and cost 50 cents per dozen more. Handles for these axes cost from $2 to $2.50 per dozen.

For each set of fallers and each bucker there is provided a steel sledge for driving wedges. Those used by fallers weigh from 10 to 12 pounds, and those used by buckers 8 pounds. The cost ranges from 20 to 27 cents per pound. In a well-equipped crew each set of fallers has four steel felling wedges weighing 8 or 10 pounds, and each bucker has three bucking wedges weighing from 4 to 7 pounds. The cost of the best steel wedges is 30 cents per pound.

Often each bucker carries an ordinary shovel. Shovels cost $8 per dozen. The limber or faller marking the log lengths uses an 8-foot marking stick, fashioned from a narrow strip of pine lumber. On steep ground or in large timber each set of fallers commonly has one or two springboards. A bottle of kerosene oil must be carried by each sawyer for the purpose of loosening the pitch which accumulates on the saw. From 1½ to 2 pints daily is required per saw, or from 1 to 1½ gallons for a crew averaging 35,000 feet daily.

A liberal tool allowance for an operation averaging from 110,000 to 120,000 feet daily, all logs bucked into short lengths in the woods, is as follows:

8 felling saws.	48 bucking wedges.
36 bucking saws.	12 felling wedges.
30 axes.	16 shovels.
20 sledges.	4 springboards.

A portable steam drag-saw for bucking at the yarders is listed at $200 f. o. b. Portland, Oreg.

OPERATION.

First the direction in which the tree is to fall is selected and the undercut is made by the undercutter or notcher. The undercutter works ahead and notches each tree with an ax in the direction it should fall, determining the lean of the tree by eye or sometimes using

his axe as a plumb line. It is then cut down by the two fallers, who work together with a crosscut saw. In thick-barked timber they usually remove with axes a ring of the outer bark at stump height before sawing. When the set consists of but two fallers, they usually prepare the undercut together, and it may be made entirely with axes or the lower portion may be sawed and the upper chopped. Saws are used for all other felling work, even in small timber. Wedges are used, when necessary, to throw the tree in the direction required.

The limbs are then cut from the merchantable bole. Limbing may follow or precede the marking of the log lengths, which is done by limber, one of the fallers, or, on some jobs, by a log marker. All limbing is done with an ax, and one man to a felling crew is usually sufficient.

Bucking is cutting the bole into logs. It is performed by men working separately, each with a crosscut saw. Wedges are used to prevent pinching of the saw, and a shovel is sometimes necessary when a log lies close to or is embedded in the ground. On some steam and all horse logging operations the logs are bucked into short lengths in the woods; that is, 12, 14, 16, and 18 feet. The more progressive steam loggers are now having the trees bucked in the woods into one, two, and three log lengths. These logs are then bucked into shorter lengths by hand buckers or portable steam saws at each yarder, or by a steam drag saw in the mill pond or on the mill deck.

The standard felling and bucking crew consists of one set of two fallers, one limber, and five buckers. In average timber the average output of such a crew is from 35,000 to 40,000 feet daily. If an undercutter is added, three buckers must also be added, one of whom helps with the limbing. The average daily output of such a crew is about 55,000 or 60,000 feet. Thus, under ordinary conditions each faller is good for from 18,000 to 20,000 feet daily and each bucker for from 8,000 to 9,000 feet.

The daily wages of the smaller crew are from \$23 to \$24 daily, usually the former. Under excellent felling conditions, one more bucker is required, making the daily cost \$25.75; and under severe conditions one less bucker is necessary, thus decreasing the daily cost to \$20.25. On this basis the labor costs of crews of this type are about as follows:

1. Very unfavorable conditions, 26,000 feet daily, 78 cents per 1,000.
2. Poor timber, 30,000 feet daily, 72 cents per 1,000.
3. Fair timber, 35,000 feet daily, 65 cents per 1,000.
4. Ordinary timber, 38,000 feet daily, 60 cents per 1,000.
5. Good timber, 40,000 feet daily, 57 cents per 1,000.
6. Very good timber, 45,000 feet daily, 54 cents per 1,000.
7. Excellent condition, 50,000 feet daily, 51 cents per 1,000.

A labor cost of 60 cents per 1,000 would ordinarily be divided between the different steps of the operation in about the following proportion: Felling, 19 cents; limbing, 7 cents; bucking, 34 cents.

In the very rough timber on the east slope of the Sierras an extra limber is often required at an additional cost of $2.75 per day, or normally 7 cents per 1,000.

The addition of an undercutter and extra buckers increases the output but does not materially affect the cost. The advantage of a very expert undercutter is a saving in breakage. Further, the enlarged crews sometimes fit in better with the size of the logging operations. For example, a small single band mill might be served more cheaply by one set of three fallers than by two sets of two each.

In logging operations where the logs are yarded in long lengths, the standard crew under ordinary conditions is two fallers, one limber, and two buckers. The average daily labor cost of such a crew is $15, which amounts to 50 cents per 1,000 at 30,000 daily; 43 cents per 1,000 at 35,000 daily; 40 cents per 1,000 at 38,000 daily; and 37 cents per 1,000 at 40,000 daily.

Two systems are employed for bucking long logs into short lengths at the yarding engines. The first is used only in the smaller timber of the pure yellow-pine stands, where the work is done by hand. Two men are required at a machine averaging from 25,000 to 30,000 daily and three men at a machine yarding from 38,000 to 40,000. The cost is 23 cents per 1,000 for a machine averaging 26,000 feet per day; 20 cents for one averaging 30,000; 24 cents for one averaging 35,000; and 21 cents for one averaging 40,000. Thus it appears that this system does not reduce the cost of felling and bucking. The saving comes in yarding. In the larger timber a portable steam saw does the bucking at each yarder. Steam is furnished by pipes from the donkey boilers. A 20-foot metallic hose may connect the pipe to the saw in order to permit the saw being moved from one log cut to another. If a hose is not used, each log cut must be spotted at the saw. Two men are required to operate a saw of this type. The daily cost, including upkeep, is about $6. The maximum amount that may be sawed daily is 80,000 feet, or well in excess of the output of any yarder in this region. The cost of sawing is 23 cents per 1,000 at a machine yarding 26,000 daily; 20 cents at one yarding 30,000; 17 cents at one yarding 35,000; and 15 cents at one yarding 40,000. Thus this system lowers the cost of bucking in all cases where the average amount yarded daily per machine is in excess of 30,000 feet.

Many concerns situated in northern California log in lengths up to 32 or 40 feet as far as the mill pond. Logs over 20 feet in length are then bucked once with a steam drag-saw which is located on the pond or just inside the mill. This system saves considerable in

bucking and apparently does not increase railroading expenses. The practice of bucking into short lengths at the yarders prevails for chute and most narrow-gauge railroad logging. The method of crosscutting at the mill is becoming more common as the use of chutes decreases and more standard-gauge logging railroads are built.

Felling and bucking is frequently done by contract, usually more cheaply than by day labor. This advantage may, however, be offset by carelessness in felling. Either for this or some other reason most concerns avoid the contract system. The contract rates vary from 15 cents per thousand for felling and 25 cents for bucking on a very favorable operation, the company to furnish and fit tools, to 65 cents per 1,000 for the entire felling and bucking operation under ordinary conditions. Upon one National Forest timber sale area the felling and bucking is contracted for at 75 cents per 1,000.

Peeling the logs is done only in horse logging operations. The larger logs are usually peeled on one side and sniped on the small end. The cost is about one man's time for an operation of from 30,000 to 40,000, or from 7 cents to 10 cents per 1,000. Sniping the ends of the larger logs is also done on some donkey logging operations in heavy timber and loose granitic or volcanic soil. A member of the yarding crew does such sniping in connection with knotting and swamping.

MAINTENANCE.

Saws and axes for felling and bucking, with ordinary use, should last from a half to a full season. The other equipment should last for a season or more. The annual cost of tools and equipment for an ordinary felling and bucking crew is estimated at $250; or 5 cents per 1,000 feet, if the daily output is 35,000. A cheap grade of kerosene is used for the saws, and its cost under any conditions does not exceed one-half cent per 1,000.

One saw filer can easily fit from 10 to 12 saws daily, and 14 by working hard. Fallers use a saw from 1½ to 2 days without refitting, and buckers about 1½ days. Therefore one saw filer can care for the saws of three ordinary sets of fallers or two three-man sets. Thus, ordinarily, there is a saw filer at each camp. The use of steam saws does not make much difference in the amount of saw fitting. The cost of fitting is usually about 4 cents per 1,000, though it may run up to 6 cents.

The cost of maintenance and supplies for felling and bucking is about 8 cents per 1,000 under favorable conditions; 10 cents per 1,000 under normal conditions; and 12 cents per 1,000 under adverse conditions.

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FROM STUMP TO YARD.

After felling and bucking, the logs are collected and taken from where they lie in the woods to a common point from which they are transported to the mill. This common point, or yard, is, in the case of steam logging, at the yarding engine, which may be on a chute, or roading trail, or at a railroad landing. In horse logging the yarding may be terminated at a chute, at a railroad landing, or at a loading point for trucks. In addition to being the first step in log transportation, this is the shortest from the standpoint of distance covered. In the California pine region three methods are in vogue, namely, horse skidding, big-wheel yarding, and donkey yarding. Overhead yarding is becoming established as a fourth.

HORSE SKIDDING.

The simplest method of yarding logs in California is dragging or snaking them along the ground with one or more horses. Especially in the more open yellow and Jeffrey pine stands this method is commonly employed at small mills for delivering the logs to horse chutes or trucks. Ordinarily, no roads or other improvements are necessary, it being simpler to go around obstacles. The logs are always bucked in the woods into short lengths, and usually hauled singly.

Equipment.—The skidding teams range from 2 to 6 horses each, depending upon the distance and the size of the loads. Only heavy work horses costing about $250 each are satisfactory. Such horses average about four or five seasons in the woods; and though some can be sold for a trifle at the end of that period, the annual depreciation is from 20 to 25 per cent, depending upon the severity of conditions. Allowing for 150 working days, the daily depreciation on a horse is estimated at from 38 to 40 cents. To this amount must be added from 75 to 85 cents per day for care and feeding, and about 8 cents for shoeing. A slight additional cost occurs in winter pasturage and in delivery to and from pasture. Thus the average daily cost of horse labor is about $1.40 per horse.

A set of logging harness for two horses costs from $50 to $60. The remaining necessary equipment consists of a pair of spreaders for each span and a heavy draft chain to extend from the log to the leaders. This chain may be passed around one end of the log and fastened with a grabhook, or it may be attached to a short chain fastened to the log with so-called grabs or dogs. In small timber tongs may be used to hitch a single team to the logs. Logs are sometimes fastened together into trails of two by means of a short chain with grabs on either end.

Doubletrees or spreaders cost about $4 per pair, if of wood; and $8 per pair, if of steel. The net cost of horse skidding tongs is about

$4 per pair. Swampers should be outfitted with both a double-bit ax and a crosscut saw.

Operation.—The advisability of horse skidding is determined primarily by the size of the operation and to some extent by the length of the haul. For small circular mills, whose investment must be limited, it proves satisfactory under favorable conditions, such as smooth surfaces, preferably sloping, and timber of moderate size. It is also adapted to slopes (over 20 per cent) too steep for big wheels or trucks. In large operations, areas not suited to big-wheel logging can be yarded more economically by steam contrivances unless the skid haul is very short indeed. A large company located advantageously for a combination of horse snaking and horse chute hauling has during the last few years effected a considerable economy by changing to donkey yarding with increased railroad spur construction. Horse logging on National Forest timber sales is desirable from the standpoint of the silviculturist, because it does less injury to reproduction and uncut trees; but even where it is practicable, the difference in cost is usually so great that it can not reasonably be stipulated in the sale contract. In horse logging the logs may be simply bunched, or they may be hauled as far as 600 feet from either side into chutes or to truck landings. This distance seems usually to be the maximum at which the most effective work is done. Instances are on record, however, where conditions were such that the maximum haul was double this distance. The maximum slope for horse snaking is about 45 per cent.

The simplest form of snaking is rolling and bunching logs together in a position for loading on a truck, when the tract is so gentle in slope that logs may be loaded from practically any point. It is practicable in certain open yellow pine and Jeffrey pine stands. A crew consisting of a swamper and a teamster working with a two-horse team ordinarily furnishes and helps load enough logs for one truck, working on a mile haul. The daily labor and team cost is $9; and with a daily output of 13,000 feet, the average cost is 70 cents per 1,000. In a similar operation on steeper ground, where truck roads are so constructed as to permit the trucks being brought into fairly close proximity to the logs, the average daily output is about 38,000 feet. The crew consists of three swampers and three teamsters with three four-horse teams. The total daily labor and team cost is $36, which is an average of 95 cents per 1,000.

Experience in pine on the eastern slope of the Sierras has shown that in skidding to chutes eight horses, divided into two four-horse teams, working a maximum distance of 600 feet, should put in from 20,000 to 25,000 daily. The crew required is two teamsters and two swampers, and the total daily cost is $26. Thus, under ordinary conditions, the cost should range from $1.05 to $1.30 per 1,000. A

concrete example of what may be done under favorable conditions is shown by an operation skidding from 300 to 400 feet into chutes. The daily output is 40,000 feet; and the logs are medium sized sugar and yellow pine, many so large that one side must be peeled. The crew consists of two men sniping and peeling logs, two men swamping, two men with a two-horse rolling team each, and two men with a six-horse skidding team each. The slopes are favorable and the smaller logs are dogged together in trails of two or three. At going wages the cost is about $1.10 per 1,000.

Maintenance.—The principal cost of keeping up a horse skidding operation is depreciation on the horses. The upkeep of tools and other equipment is very light, not in any case more than 4 or 5 cents per 1,000.

BIG-WHEEL YARDING.

Logging to railroad spurs by big wheels is the same operation as is commonly designated in the Lake States and the South as logging with high-wheel carts. Ideal conditions are offered by short hauls, smooth surfaces, absence of underbrush and débris, flat land or gentle slopes, and moderate sized timber. In most of the California pine region the slope is too steep, but the big wheels are used on the east slope and in many places on the west slope of the Sierras. They are used most extensively in the Mount Shasta region.

Ordinarily, no road construction is necessary in big-wheel yarding; but a small amount is required at points where some obstacle makes it necessary to haul to a landing contourwise of the slope or on flats thickly strewn with lava rock, which must be cleared out of the main roads in case of long hauls. The landings are two 6-inch poles placed parallel and at right angles to a loading spur, with a slight excavation between the poles. The construction of one might require the time of one man for one-half day. Slip-tongue big wheels require no landings.

Equipment.—There are two types of big wheels in use. One is the stiff-tongue or Michigan logging wheel. The size used under most conditions has wheels 10 feet in diameter, a 6-foot tread, and 6-inch tires. Where the ground is not too soft a 4-foot log may be straddled. The axle is wooden; and the tongue, which is a small pole fastened rigidly to the axle, is about 16 feet long. The cost is $135 each f. o. b. the factory in Michigan, which would represent about $200 delivered. Twelve-foot wheels, with arched iron axles, designed for large timber, are manufactured locally in California. The cost is about $250 f. o. b. factory. The other style of big wheel is the so-called slip-tongue, designed for steeper ground and longer hauls. The variety in use here has 10-foot wheels, 6-inch tires, a 6½-foot tread, and a 30-foot tongue. The weight fully equipped is 3,600 pounds, and the price, f. o. b. the California factory, is $350.

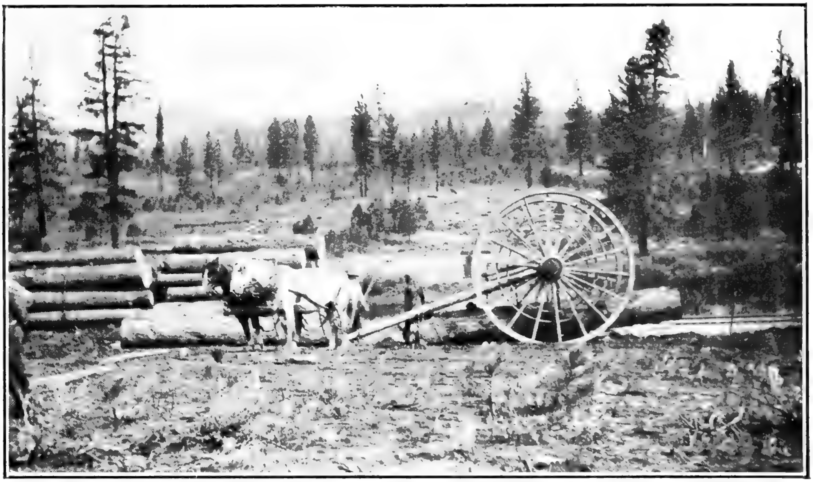

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FIG. 1.—A PAIR OF STIFF-TONGUE BIG WHEELS AT THE LANDING, READY TO UNLOAD.

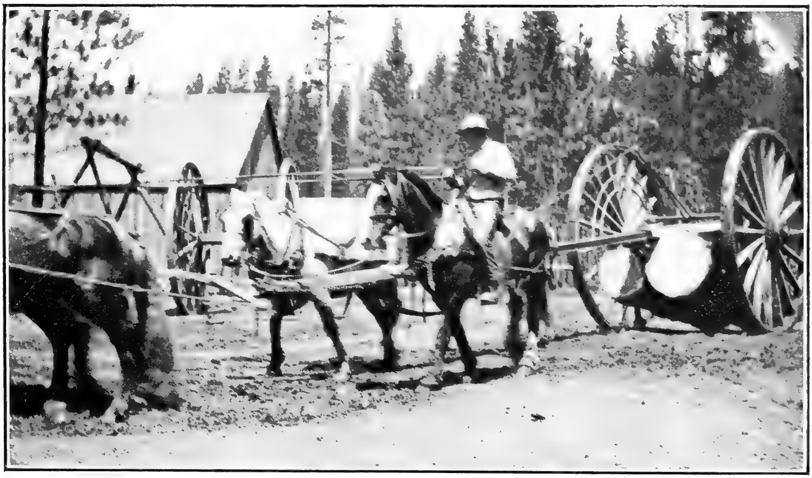

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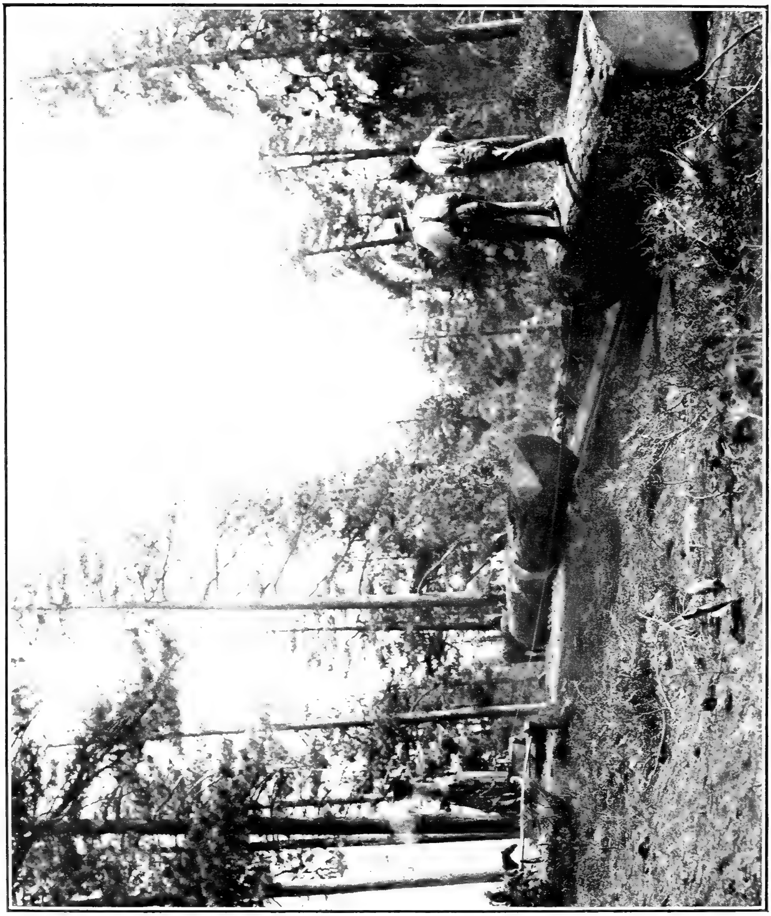
FIG. 2.—SLIP TONGUE BIG WHEELS WITH A LOAD OF LOGS, ARRIVING AT A MILL POND.



F-95302

FIG. 1.—YARDING INTO A CHUTE WITH A DOLBEER DONKEY ENGINE. YELLOW PINE STAND IN THE EASTERN SIERRAS.

F-15755-A

FIG. 2.—A 10 BY 11 TANDEM DRUM YARDER WORKING AT A LANDING ON A LOGGING RAILROAD.

The horse and harness equipment is substantially the same as for horse skidding. Each swamper and knotter requires an ax and each gopher an ax and shovel. Each bunching team requires a pair of spreaders, a pair of tongs, and a rolling hook.

Operation.—The operation begins with swamping, which may consist simply of moving the limbs out of the way or may involve cutting a broad road to each tree through thick manzanita and snow-brush. Where there is little or no underbrush, about one swamper is required to each two pairs of wheels, which means in a camp turning out 120,000 daily a crew of four men at a daily labor cost of $10, or 8 cents per 1,000. In thick brush, a foreman and 16 men are required for an operation of the same size. The labor cost is $38.75 daily, or 32 cents per 1,000. Thus, the swamping cost is about as follows: Stands without underbrush, 10 cents per 1,000; stands with heavy underbrush, 20 cents per 1,000; and stands with very heavy underbrush, 30 cents per 1,000. Swamping for slip-tongue big wheels usually costs a trifle more, because more room is required for turning.

After swamping is completed, the logs are bunched; i. e., they are broken apart and dragged or rolled into position for the wheels. This may vary slightly according to the wheel used, because slip-tongue big wheels usually carry bigger loads. Under favorable conditions, two bunch teams supply seven stiff-tongue big wheels, and under ordinary conditions should serve six. With each bunch team is a teamster, a hooker, a gopher, and a knotter. The knotter trims off all limbs remaining on the logs and assists the gopher in making an opening under each load for the binding chain.

Stiff-tongue big wheels are used to advantage on slopes from level up to 12 per cent; and, when it is necessary, may be used on 15 per cent slopes. Work on heavier slopes is not practicable. The maximum hauling distance for efficient work is about one-fourth mile, though sometimes one-half mile and longer hauls are made. Under ordinary conditions one two-horse team is sufficient for each set of wheels. On the out trip the team is hitched on the tongue in the usual manner, and when the load is reached the wheels are backed over it. The tongue is then elevated to a perpendicular position and a binding chain passed underneath the logs and attached to the axle on either side. The team then pulls the tongue to the horizontal, which tightens the binding chain and raises the logs from the ground. The front end of the load of logs and the end of the tongue are then bound together with a lighter chain; the team is hitched short up to the end of the tongue; and the load is ready to proceed.

In small open yellow-pine timber where the slopes are gentle but broken by pitches, two pairs of stiff-tongue big wheels yarding as far as 1,200 feet put in 22,000 daily. The average load consists of about 600 feet, the timber running about four logs to the thousand.

Each set of wheels makes about 19 or 20 trips daily. In addition to a team and driver for each pair of wheels, there are two men and a team to bunch the logs, and a fifth man to dig chain holes under the bunches. The cost of bunching is about $7.10 per day, or 31 cents per 1,000; and of hauling, about $15 per day, or 65 cents per 1,000. The other extreme is found in a stand of timber averaging about two logs per 1,000, where seven pairs of big wheels put in about 120,000 feet daily; maximum haul one-fourth mile. Each pair of wheels has a team and teamster. The remainder of the crew consists of four loaders, one snatch teamster, two roadmen, and one barn man. The bunching is done by two teams and crews. A snatch team is used to help start the heavier loads. The cost of hauling is $60 daily, or 50 cents per 1,000; and the cost of bunching, $26 daily, or 22 cents per 1,000. Under conditions only moderately favorable, the average daily output to be expected would be about 100,000, at a cost of 86 cents per 1,000.

Owing to the weight of the so-called slip-tongues, four horses must be used on each pair. A four-horse team will haul a pair of these wheels up a grade of from 17 to 20 per cent. On heavier grades the wheels must be pulled back over the logs with a cable. When loaded, they will readily come down over pitches of 35 per cent; also a slight adverse grade can be overcome. They can be used on longer hauls; the maximum (where truck hauling becomes cheaper) is reported to be 1½ miles. The reason for these differences in operation lies in the slip-tongue device. The tongue, which slides forward or backward at will, is attached by a long rod to a lever, which is in turn connected with an iron shaft on the top of the axle which tightens or slackens the binding chains. Thus, when the load drags, the tongue is pulled forward and the load raised, which lightens the draft; conversely, when the wheels run ahead, the tongue slides back and the load is allowed to drag and act as a brake.

On a mile haul with fairly good level road about eight round trips are made daily. The average load is about 1,100 feet, making an output of 9,000 daily. The labor cost is $9.50 per day, or $1.06 per 1,000. One bunching team with two men and one swamper is required in the woods for the two wheels. The cost of bunching is about 44 cents per 1,000; and the cost of swamping, 14 cents per 1,000. On a haul of about one-fourth mile a set of slip-tongue high wheels makes 14 trips daily with an average load of 1,200 feet. A team and one man is required for bunching. The cost is about $1 per 1,000 for both hauling and bunching.

Stiff-tongue big wheels are superior for short hauls and good ground. The slip-tongue type is better for long hauls and slopes over 12 per cent. The slip-tongues are sometimes undesirable on timber-sale

areas, because of the large amount of swamping required to give room in which to turn them.

Maintenance.—The maintenance of big wheels varies with the size of the camp and the length of the haul. For large camps on one-eighth mile hauls, 5 or 6 cents will cover the tool charge and 10 or 15 cents per 1,000 will meet the repairs. On very long hauls probably 25 cents per 1,000 should be allowed for maintenance.

STEAM-DONKEY YARDING.

The most common method of yarding logs throughout the region is by hauling on the ground with donkey engines and wire ropes or cables. From 75 to 80 per cent of all the timber cut is yarded in this way. This method is variously known as donkey yarding, slack-rope yarding, or steam yarding. It is used by all the larger companies, because it is adapted to a wide range of conditions. Horse logging by large firms is confined to favorable areas, donkey engines being used on all the more difficult ground. Small outfits use horses because of the short life of the operations and the need for limiting the amount invested.

The yarding donkeys are of all types from the light Dolbeer or spool donkey to very heavy and powerful double-drum machines. The principle involved is the same in all: The logs are hauled in from the woods to the machine by means of a wire rope wound on a drum or spool, and the cable is returned to the woods by means of a horse or of a smaller return cable.

The yarders may be set on railroad spurs, at chutes, or on roading trails. In the case of settings on railroad spurs, the yard and landing are identical and that part of the operation termed "from yard to landing" is eliminated. The most efficient loggers are adopting this practice, having found that under practically all conditions it is economy in the end to construct a heavy mileage of logging railroad, thus decreasing yarding distances and eliminating chuting or roading.

Improvements.—Blasting stumps out of yarding trails is usually unnecessary. Only rarely are stumps blasted out and then it is done incidentally by some member of the yarding crew. As the use of large high-speed machines increases, the blasting of stumps may become more common.

Landings of some sort are necessary at practically all donkey settings on loading spurs, except when the donkeys are equipped with A frames. Good landings pay for their construction by eliminating delay in both yarding and loading. On sloping ground they include excavations or frameworks for setting the donkey. The cheapest kind is made by placing two logs parallel at right angles to the track. The type used for loading with a gin pole and cable with end hooks or skids consists of two or three logs at right angles to the track and

bumper logs on one or both sides of the track. The cost differs with the amount of clearing and grading necessary. The average is from one-half to one day's work for a yarding crew, or from $20 to $40 each, or say, 2 cents per 1,000. In the open stands of yellow pine a combined bucking chute and landing is used. The landing consists of three logs and a bumper log, and the chute is about 250 feet in length. The average cost is $100, or about 7 cents per 1,000. The most expensive type of landing is that used in a long logging operation on very steep ground. A large excavation must be made in the upper bank of a railroad cut, and bucking chutes 250 feet long are built out in two directions. The average cost is about $300 each, or approximately 8 cents per 1,000.

Equipment.—Donkeys are ordinarily classified by the size of the cylinders, the diameter being given first. The original yarding donkey was the Dolbeer or spool type, which is now used mainly for chute and trestle construction. The standard size Dolbeer has a single 6 by 12 inch cylinder and weighs about 8,000 pounds. The boiler is 36 by 6 inches and carries 160 pounds of steam. It is manufactured in San Francisco and the cost f. o. b. factory is about $1,000. This type has a spool for the yarding line and may have a single drum for the back line. The usual maximum yarding distance is 800 or 1,000 feet.

Practically all the other machines used are return line. All of the engines have two cylinders and are connected by gears to the shafts of two drums, one for the yarding line and one for the back line. These gears may be either direct or compound. Compound gears give greater speed. The drums, placed either tandem or opposite, rotate upon their shafts and are held fast when pulling by means of frictions, which are applied by hand levers. The newer and larger yarding engines have steam frictions on the main drum. A spool or small friction drum may be attached to the shaft of the main drum for loading purposes.

The boilers are upright, ranging in size from 48 inches in diameter and 118 inches in height to 72 inches in diameter and 144 inches in height. Some of the newer types have so-called extension fire boxes which give larger firing space. The boilers of the older types of engines carry about 160 or 165 pounds of steam. The newer types carry from 175 to 200 pounds. It is important in any yarder to have sufficient boiler space to keep up steam pressure, especially in the mornings or after showers, when the fuel is wet.

Small machines, such as 10 by 11 inch tandem drum yarders, and 9¼ by 10 inch and 9 by 10¼ inch compound yarders, are used in the yellow pine stands on the east side of the Sierras. Light, rapid machines which can be readily moved are required because the timber is small and the stand open. Machines of these sizes are usually sup-

F-15946-A

FIG. 1.—A 12 BY 14 YARDER AT A RAILROAD LANDING IN THE SUGAR PINE REGION.

Logs yarded in long lengths and bucked in chute. Separate loading engine below track.

F-15960-A

FIG. 2.—STEAM BUCKING SAW USED FOR BUCKING AT YARDING ENGINE.

F-66788

FIG. 1.—HAULING LOGS IN A TYPICAL HORSE CHUTE IN THE SUGAR PINE REGION.

F-11871-A

FIG. 2.—A TRAIL OF LOGS IN A DONKEY CHUTE.

A small yarding engine making up a trail of logs and chute trestle, in the foreground, are shown.

plementary to larger engines. The maximum yarding distance is usually from 1,000 to 1,300 feet. The larger timber, where logging conditions are good, is mostly yarded by slightly larger machines, such as 10 by 12 inch and 10 by 13 inch tandem drum yarders, and 10½ by 10¼ inch and 10 by 11 inch compounds. The maximum yarding distance usually ranges from 1,300 to 1,600 feet.

The machines commonly used for logging in the harder chances in the Sierras, where long hauls and uphill pulls are necessary, are still larger. The smallest are 11 by 13 inch yarders and the largest 12 by 14 inch. The latter are the largest on the market. The maximum yarding distance is usually 2,000 feet, sometimes 2,200 feet. The tendency is to replace worn-out yarders by larger machines, and the manufacturers have accordingly been turning out larger engines each year.

Table 3 gives the approximate prices, f. o. b. factory, for yarding engines.

TABLE 3.—*Prices of yarding engines.*

Size.	Boiler.	Weight.	Cost.
Inches.		*Pounds.*	
10 by 13	60 inches diameter	....	$2,650
8½ by 10	44 inches diameter	15,000	1,750
9¼ by 10	48 by 118 inches	23,000	2,450
	Oblong, 48 inches	25,000	2,600
10 by 11	60 by 126 inches	30,500	2,950
	Oblong, 54 inches	33,500	3,350
11 by 13	66 by 125 inches	37,500	3,500
	Oblong, 60 inches	40,000	3,900
12 by 14	72 by 144 inches	45,000	4,350
	Oblong, 66 inches	50,000	4,800
10 by 11 (tandem)	60 by 126 inches	28,000	2,750
	Oblong, 54 inches	....	3,000
11 by 13	66 by 125 inches	37,000	3,650
	Oblong, 60 inches	....	3,900
9 by 10¼	48 by 106 inches	25,000	2,500
10½ by 10¼	60 by 106 inches	29,500	3,050
11 by 11	66 by 120 inches	35,000	3,500
12 by 12	72 by 120 inches	40,000	4,000
9¼ by 10	48 inches round	22,500	2,400
	54 inches extension	24,500	2,650
10 by 12	54 inches round	29,000	2,850
	54 inches extension	....	3,050
12¼ by 12	68 inches round	43,000	4,000
	68 inches extension	....	4,250

The approximate cost of most yarding engines can be arrived at by allowing 10 cents for each pound of weight.

Freight to California points is about $200 on small engines, $250 on medium, and from $300 to $350 on large engines. In addition each yarder must be equipped with a sled. These range in length from 20 feet for small yarders to 40 feet for large machines. They are usually built by the logger and cost from $200 to $300 each. Either wooden or steel water tanks are built for each machine and placed on the rear of the sleds. The steel tanks give the best service and cost from $100 to $200 each, depending upon the size of the machine. Usually a shelter with a corrugated iron roof is placed

on the machines after they arrive in the woods. Three types of efficient spark arresters are in use, varying in price from $12 to $45.

Because of the increase in size of yarding engines, there is a tendency to use heavier wire rope for yarding. At present the most satisfactory sizes for main lines are 1 inch for the small yarders, 1⅛-inch for all ordinary yarders, and 1¼-inch for the larger yarders in rough country with uphill hauls. The universal back line is five-eighths inch, except for very small machines, upon which one-half inch is sometimes used. Dolbeers are commonly equipped with seven-eighths-inch main line and three-eighths-inch back line.

Wire rope for logging is commonly quoted at list prices upon which certain discounts are allowed, varying from time to time with the price of steel. There are two grades, plow steel and extra plow steel. Most logging rope is the latter grade. Yarding rope is commonly composed of 6 strands of 19 wires, each about a hemp center. On account of its greater pliability, rope having 8 strands of 19 wires each is preferred for chokers. Table 4 gives approximate net prices in 1914 per linear foot for standard logging wire rope f. o. b. San Francisco.

TABLE 4.—*Approximate net prices for standard logging wire rope in 1914 at San Francisco.*

Diameter.	Weight per foot.	Plow steel, 6 by 19.	Extra plow steel, 6 by 19.	Extra plow steel, 8 by 19.
Inches.	*Pounds.*	*Per foot.*	*Per foot.*	*Per foot.*
½	....	$0.06	$0.08	....
⅝	0.62	.085	.11	$0.12
¾	.89	.115	.15	.17
⅞	1.20	.15	.19	....
1	1.58	.19	.245	.27
1⅛	2.00	.24	.30	.33
1¼	2.45	.29	.37	.40
1⅜	3.00	....	.44	.48
1½	3.55	.41	.54	.58

Usually four or five chokers are kept on hand at each machine. Each consists of a piece of cable from 15 to 30 feet in length, having a loop on one and a choker hook on the other. They may be made of old yarding cable or new 1-inch 8 by 19 strand.

The proper block equipment for a yarder consists of two "Tommy Moores" or "Jumbos" for the yarding line, and one head or tail block and about six 10 or 12 inch trip-line blocks for the back line. Shackle yarding blocks are still used in a few instances but are rapidly being supplanted by the "Jumbos," since the latter permit the passage of the butt hook and chokers on the outward trip. A moving block is sometimes added to the equipment of a yarder, though usually one of the "Jumbos" is used for moving. Table 5 gives the approximate cost of the best grade of logging blocks f. o. b. San Francisco.

TABLE 5.—*Approximate cost of best grade of logging blocks.*

Kind of block.	Size of sheave.	Weight.	Cost.
	Inches.	*Pounds.*	
Trip line	10 by 1	52	$15
Tail block	15 by $1\frac{1}{4}$	132	25
Do	19 by $1\frac{1}{4}$		35
Yarding block	8 by 2		21
Do	10 by $2\frac{1}{4}$		25
Do	12 by $2\frac{1}{2}$	146	30
Tommy Moore	14 by 8		50
Do	16 by 8		60
Moving block	18 by $2\frac{1}{2}$	230	50
Roading and yarding spool	14 by 8	210	45

In addition to blocks, so-called "fair-leaders" are placed on the front of the sleds of narrow drum yarders, for the main line and sometimes for the back line. The cost ranges from $50 to $100 each, depending upon size.

Operation.—Yarding begins with the moving of the machine to its setting, which may be either on a railroad spur, a chute, or a roading trail. After the machine is set, the back or trip line is hauled out by a horse around several runs, passed through the tailblock and returned to the donkey along the line of the first run. The outer end of the main line is then attached to the back line by means of a clevis. A short piece of cable terminating in the heavy butt hook is fastened to the end of the main line for the purpose of attaching chokers. Since the donkey is usually set parallel to the track or chute, a Tommy Moore is ordinarily placed at a distance of from 200 to 250 feet from the donkey, for a main lead block. Its purpose is to steer the logs into a bucking chute, or to bring them in parallel to the track for loading, and to give the cable the right lead for spooling on the drums. A second Tommy Moore may also be used farther out in the woods when it is necessary to avoid obstacles or change the direction of the lead. The trip line blocks are placed at intervals on the back line to hold it up from logs and rocks.

When the cable has been strung and everything is in readiness for logging, the back line is reeled up on the return drum and the main line hauled out to the first log. A choker has previously been hooked around one end of the log. The free end of the choker is attached to the butt hook and the main line is reeled in, bringing the log with it. The log must be stopped at the lead block, slack pulled in the main line by the back line, and the choker unhooked and passed around the block. At the landing the choker is unhooked and the line returned to the woods for another log.

Each round trip is designated as a turn. The common trail made by the logs taken in from one location of the tail block is called a run. When a run is completed the tail block and back line must be shifted to the next run. One, two, or three logs may be brought in

at a turn, depending upon the size of the logs and the power of the machine. One log is by far the most common. The logs may be in single, double, or triple lengths.

The territory yarded from a setting is usually in the form of a more or less complete irregular half circle or half square with the center at the main lead block. The runs extend from this common center in the form of radii. Two settings are often made at the same landing.

The members of the yarding crew are stationed both in the woods and at the machine. The swampers do whatever clearing of limbs and brush is necessary, trim off knots and limbs left on the underside of logs, and snipe large logs when necessary. Either one swamper or a special man, termed variously gopher and choker hole digger, digs holes under one end of each log to allow the passage of the choker. Each swamper is equipped with an ax and the choker hole digger with an ax and shovel. The riggers or rigging slingers put the chokers on the logs and hook on the butt hook. Each yarding donkey is in charge of a logger or hooktender. He usually stations himself along the run where both ends of the operation can be observed. He issues all orders, and plans the arrangement of the lines and the location of the runs. The frogger or blocktender is stationed at the main lead block. He also unhooks and sends back the chokers at the landing. If dirt and débris collect at the frog or landing, they are cleared away by a frog shoveler. A whistle punk stationed in the woods transmits signals by jerking a wire attached to the whistle of the donkey. He also drives the line horse in stringing cable. An engineer and fireman are required at the engine. The men engaged in cutting and packing wood are termed woodbucks. When men are required to pack water on mules or horses they are called waterbucks.

The Dolbeer donkey, when it is used for yarding, is placed on short hauls, about 600 or 800 feet. The logs are invariably yarded in short lengths, though several small logs may be brought in at one time. Several small yarding blocks are used, the principle being to go around obstacles rather than over them. The inhaul is very slow but powerful, and logs can be taken up very steep slopes. When located on a railroad spur, the Dolbeer does its own loading, which necessitates a delay in yarding of about one-half hour for each car. The usual output under these conditions is from 16,000 to 19,000 daily. When yarding is done into a chute, the output is about 15 per cent greater. The standard crew for a Dolbeer consists of 1 logger, 1 engineer, 1 spooltender, 1 lookout, 1 linehorse driver, 3 swampers, and 1 woodbuck. One horse is required for shifting the line. Water is supplied by pumping.

The most efficient donkey logging in the yellow pine and white fir of the East Slope region is done on an operation using 10 by 11 inch and 10 by 13 inch machines, both direct and compound geared. The logging chance is excellent. The stand is well distributed and the timber medium sized, about three logs per 1,000 and five logs per tree. The average stand is from 20,000 to 25,000 per acre. The surface is smooth and the slopes moderate, mostly from 10 to 20 per cent. The railroad is so built that the actual maximum distance is from 1,300 to 1,400 feet. Logs are hauled in long lengths and bucked by hand at the yarders. The amount yarded daily averages from 36,000 to 40,000 for the season. The crew at each machine is composed of 1 hooktender, 2 rigging slingers, 2 swampers, 1 whistlepunk, 1 frogger, 1 frog shoveler, 1 engineer, and 1 fireman. Water is supplied through pipes by pumping and gravity. Slab wood from the sawmill is used for fuel.

Compound machines 10½ by 10¼ inches and 10 by 13 inches are used in the northern portion of the East Slope. The timber here is large, averaging less than two logs per 1,000. The stand is patchy and averages about 20,000 per acre. The surface is smooth but very brushy and the slopes are moderate, averaging about 20 per cent. The logs are cut into both single and double lengths, though mostly into single lengths, because of their large size. The average seasonal output is from 25,000 to 26,000 per day. The approximate maximum yarding distance is 1,400 feet. Each donkey crew is made up of 1 hooktender, 1 head rigging slinger, 2 riggers, 1 choker-hole digger, 1 knotter, 1 whistlepunk, 1 engineer, and 1 fireman. Fuel is supplied by cutting white fir trees into wood, loading this wood on flat cars, and hauling it to each yarder. Water is scarce and is supplied in tank cars. A line mule is used for stringing line.

A typical operation in the sugar and yellow pine of the southern Sierras combines small tandem drum donkeys for hauls up to 1,200 feet and large 11 by 13 inch moguls for distances up to 2,000 feet. The stand averages from 30,000 to 35,000 per acre, and the trees average from six to eight logs. The country is rather rough and the chance of more than average difficulty. The slopes are steep, ranging from 25 to 50 per cent. The plan of logging involves a railroad along the main stream with chutes up the slopes into the timber. The logs are yarded in double lengths and bucked with steam saws. The smaller machines put in from 23,000 to 25,000 feet daily, with the following crew: 1 logger, 2 swampers, 1 rigger, 1 lookout, 1 frogger, 1 frog shoveler, 1 engineer, 1 fireman, and 1 woodbuck. The larger machines average from 28,000 to 30,000 daily, and have the following crew: 1 logger, 1 head rigger, 2 riggers, 2 swampers, 1 whistlepunk, 1 frogger, 1 frog shoveler, 1 engineer, 1 fireman, and 2 woodbucks.

Water is supplied both by pumping and by gravity. A horse is required at each machine for shifting cable when changing runs.

One company in the southern Sierras uses 12 by 14 inch yarders with 1¼-inch cable for yarding distances up to 2,000 feet. The country is one of steep slopes on both sides of numerous streams in a common watershed. The logging railroad follows contourwise along these slopes. The machines are set along the railroad, and the logs are yarded to the track, both up and down hill. The slopes above the track range from 25 to 40 per cent, and those below the track from 40 to 70 per cent. The surface is smooth and there is little underbrush. The virgin stand is about 40,000 feet per acre. The logs are yarded in long lengths and bucked at each yarder with a steam saw. The daily output is about 38,000 or 40,000 feet, with the following crew: One hooktender, 1 frogger, 3 riggers, 1 chokerhole digger, 2 frog shovelers, 1 whistlepunk, 1 engineer, 1 fireman, 1 woodcutter, and 1 wood teamster.

The average outputs given in the above examples include a time allowance for moving donkeys, but not the building of frogs or landings. It is usually more economical to have landings built by separate crews than by the yarding crew. In easy country a donkey will make the usual one-fourth or one-third mile move under its own power in one-half day. In rough country double that time is required. The donkeys are frequently moved on flat cars on the logging railroads. From three-fourths to one day is required for such a move, regardless of distance. Moving time is measured from the bringing in of the last log on one setting until the line is out ready for logging on the next. Light donkeys are moved more quickly than heavy ones. The period between moves depends upon the output of the donkey, the stand per acre, and the area of the setting. It usually ranges from three weeks to two months.

The usual time of changing a tailblock from one run to another is from 20 to 30 minutes, depending upon the character of the country. More difficult changes, or changes around several runs, require from 30 to 50 minutes. Eliminating very unfavorable settings, the average time required for a turn is about 15 minutes. On short hauls, it may be as low as six or seven minutes, and on long difficult hauls, as high as 25 minutes. The size and speed of the machine and the character of the timber and topography all affect the time of a turn, but when delays due to loading, bucking, or frogging are considered, the average for most operations is about four turns per hour. The following information regarding the time of logging turns is intended only to give the approximate relation of the various parts of each turn. In a yellow-pine stand under very good conditions a 10 by 11 inch tandem drum yarder hauling 1,200 feet averaged a turn in 13

minutes, divided as follows: Outhaul 3, hooking three-fourths, inhaul $3\frac{1}{4}$, hungup $4\frac{3}{4}$, block one-half, and landing three-fourths minutes. A compound geared machine under the same conditions, yarding from 900 to 1,000 feet, made an average turn in $8\frac{3}{4}$ minutes, as follows: Outhaul $2\frac{1}{4}$, hooking one-half, inhaul $3\frac{1}{4}$, hungup $1\frac{1}{4}$, block one-half, and landing 1 minute. Delays waiting for steam brought the average up to 11 or 12 minutes. A 10 by 12 inch tandem drum machine, yarding from 700 to 800 feet on fair ground in large timber, with two bull blocks, averaged a turn in $13\frac{1}{4}$ minutes, as follows: Outhaul $1\frac{1}{2}$, hooking $1\frac{1}{2}$, inhaul $2\frac{1}{2}$, hungup $4\frac{3}{4}$, first lead block $1\frac{1}{4}$, main lead block three-fourths, and landing 1 minute. A 11 by 13 inch yarder in a fairly rough country averaged 14 minutes to a turn on a downhill haul of 1,500 feet. A similar machine hauling uphill 800 feet averaged 10 minutes per turn. An addition of 500 feet increased the average time by 10 minutes. Usually the average time required at a lead block is about one-half minute under favorable, three-fourths minute under normal, 1 minute under difficult, and $1\frac{1}{4}$ minutes under very difficult conditions. The time required to change a choker, on a log hungup behind a tree or stump, ordinarily varies from 1 to $1\frac{1}{2}$ minutes.

The type of donkeys selected depends upon the character of the timber and ground. The Dolbeer is apparently going out of use, because labor is too great a factor in its operation and its maximum yarding distance is too short. Small compound machines are preferred in small rather light timber where the maximum yarding distance is short. Medium-sized machines are used in larger timber under similar conditions. Slightly larger engines are adopted in localities where the chance is more difficult and the yarding distance longer. The largest yarders are used where it is desired to haul extra long distances both up and down hill and over all obstacles. Compound geared machines carry less cable than the tandem drum type. The tandem drum machines can also be used as roaders, if occasion demands. As a rule, the smaller yarders, with shorter lines, do more satisfactory work upon National Forest timber sale areas.

Operators are finding it an economy to construct more logging spurs and thus shorten the yarding distance. Hauling logs in double and triple lengths and bucking at the yarder or mill pond greatly increases yarding efficiency, if the work is well arranged. The longer sections decrease the time of hooking in the woods, follow the run better, hang up less, and yield more in scale feet, board measure, per turn. A machine should average 5,000 more daily hauling long logs than short logs. More powerful machines are required, however.

Wood is the universal fuel for yarders. Oil burning is not attempted, because of the difficulty of delivering oil at the machines.

The greater portion of the wood used consists of limbs, especially sugar pine, cut into lengths on the ground. This limb wood may be carried to the yarder by the woodbuck or packed on a mule for small machines. For larger machines, it may be dragged on a sled by either one or two horses, or hauled in a two-horse cart. In a few instances in the northern Sierras sound Douglas fir logs are cut by hand into fuel at the yarder. Some companies use slab wood cut at the mill and hauled to the woods on logging flats. Still others cut wood from white fir, allow it to season, and then deliver it to the yarders on flat cars.

The cost of supplying fuel at one of the smaller compound engines is the time of one man and a horse, or about \$3.50 per day. At the 10 by 11 inch and 10 by 13 inch machines, on the East Slope, burning slab wood, the cost is about \$4.25 per day for the time of one man and the handling of from 1½ to 2 cords at each machine. Where the split fir wood is used, the amount required daily for a 10 by 10¼ machine is 2 cords, costing \$2 each. The large 11 by 13 inch yarders require about two men and a horse to furnish limb wood, at a cost of \$5.50 per day. Similarly the 12 by 14 inch machines on long settings require two men and a light team at a cost of \$6.50 per day.

The first method of supplying water to donkey engine boilers was by packing in water bags on mules. One waterbuck and mule is required for small boilers, at a daily cost of \$3.25. Large boilers require double the force. At present this method is relegated to donkeys used on railroad and chute construction, and donkey engines are supplied almost universally by water conveyed in pipes. Where water is abundant, about one-half of the machines can be supplied by gravity. Where water is less plentiful, from three-fourths to all of the machines must be supplied by pumping. The cost depends upon the distance water must be piped and the number of machines that can be supplied from one pump. Usually two or three machines can be reached from a pump, and the daily cost for hire of pump-man, repairs to pump, and the prorated cost of stringing pipe, is from \$1.50 to \$2 per machine. The depreciation on pipe and pump varies from 44 cents to 75 cents per day. In localities where water is scarce the best method of supplying water is by means of tank cars. The daily cost, including hauling and depreciation, is from \$3 to \$3.50 per machine.

Maintenance.—A very considerable cost in yarding is the maintenance of the cables. The life of a main line varies from one-half to 1¼ seasons, depending upon the usage, the amount logged, the amount of rocks, and the general difficulty of logging. Under the favorable conditions in the yellow pine in the eastern Sierras, a 1⅛-inch main line will last from one to two months more than a season and a back line two or three seasons. The average

life under most conditions throughout the rest of the Sierras is one season for the main line and two seasons for the back line. Under favorable conditions in the central Sierras, where the soil is loose, the average life of the main line is eight months. On other operations where large machines are used on rough chances the average life is from two-thirds to one season for the main line and two seasons for the back line, with considerable splicing. Usually it will not be far wrong to estimate an average life of one season for main lines and two seasons for back lines. Main lines on Dolbeers last only about two-thirds of a season and the same is true for very large yarders working under severe conditions.

In addition to cables, supplies and repairs are included in maintenance. Supplies consist of oil, grease, tools, blocks, repair parts, etc. The amount required is of course larger for the larger machines. The cost per 1,000 is, however, much the same in different operations under similar logging conditions without much regard to the size of the operation. As a rule, it is from 6 to 9 cents per 1,000. The cost of repairs varies to some extent with the size of the operation. Large operations ordinarily have more efficient shops than smaller ones. The repair crew at the usual donkey camp of from three to five machines is one donkey doctor, one blacksmith, and one blacksmith's helper. At some of the smaller camps the helper is eliminated. On other operations one donkey doctor may look after the machines in two camps. The board and wages of the repairmen amount to from 8 to 10 cents per 1,000, of which it is judged about four-fifths is chargeable to yarding. In addition some of the heavier repair work is done at the mill shop. Also one or two machines are usually overhauled and repaired at the shop each year between logging seasons. Giving consideration to all these factors the information at hand indicates that the cost of maintenance in donkey yarding is normally from 18 to 22 cents per 1,000.

OVERHEAD YARDING.

The use of this system has only just begun in the sugar and yellow pine region. Many operators are considering it as a means of reducing operating costs, but they do not feel that the machinery now on the market meets their requirements. A few loggers have been trying out systems of their own devising during the last two seasons, and one or two standard rigs have been employed.

Two main systems are in use in the large timber of the Pacific Northwest. Both are alike in principle, having a main or standing one supported at either end, upon which a carriage is operated. In one system this main line is slacked off in order to allow the logs to be attached to the carriage; then the main line is tightened, which

lifts the log, and the carriage is hauled in. The other system provides that the main line be kept taut and sufficient slack to reach the logs pulled in the skidding line by some slack-pulling device.

The first attempt at overhead yarding in California sugar and yellow pine was made in 1913 with the first-mentioned system. It was continued through 1914 and the company considers the work so successful that a second machine is to be fitted with an overhead rig in the near future. The engine used is a three drum, 12 by 14 inch yarder, equipped with a $1\frac{1}{2}$-inch main or standing line. The usual distance between the spar tree and tail tree is 1,800 or 1,900 feet, but spans of 2,200 feet have been made. The carriage is operated on this standing line by a 1-inch skidding line and a $\frac{3}{4}$-inch haulback. The best setting is on the point of a secondary ridge, as the span may then be made across a gulch or small canyon. The rig is used both for yarding and roading, the plan for roading being to station a yarder at the tail tree and yard in for an additional 1,400 feet. Logs are hauled in one, two, and three log lengths, the average load being about 1,000 feet. A small donkey is stationed at the landing for hauling the logs in the bucking chute and loading. The average output for four summer months was 60,000 feet per day.

Two other similar rigs are being operated experimentally, with some success, in the Sierras. One operator in the northern portion of the East Slope region is using a large steel skidder, known as the universal logger. It is equipped to operate one line as an overhead or two lines as a ground skidder.

The system in which the main line is slackened and pulled sidewise to the logs could hardly be used on National Forest timber sale areas where clear cutting is not practiced. There is reason to believe, however, that under certain conditions the other system can be used, if provision is made in marking the trees for cutting. The cost of overhead machines with double sets of blocks, etc., is from $12,000 to $14,000 each, delivered on the ground. Cables are not included, and the cost of a set ranges from $2,500 to $3,000.

FROM YARD TO LANDING.

When the common yarding point is located at some distance from the landing, a step is necessary which is usually termed chuting or roading. It is usually done in chutes by horses, in chutes with donkey engines, or on the ground with donkey engines. Other possible methods are hauling with slip-tongue big wheels from yarders used on rough ground in the midst of a big wheel logging operation, and the use of overhead systems. Overhead systems similar to those used for yarding may in the future be utilized for roading across canyons, up steep grades, and down rough slopes. Extra supports could be used if necessary. Aerial tramways with frequent supports

and several tolleys will undoubtedly be used ultimately in bringing smaller timber down from considerable elevations; for example, red fir for pulpwood.

CHUTE HAULING BY HORSES.

With one exception, chute hauling by horses is used only by firms with small capital. The chutes frequently extend from the woods to the sawmill and may be as much as 8,000 or 10,000 feet in length.

A horse chute is constructed in much the same manner as a donkey chute, but it is lighter and need not be as strong. The poles used are cut either 50 or 60 feet in length, about 8 or 9 inches on the small end, and as large as 16 inches on the butt end. They are laid in two parallel rows about 5 inches apart, the ends being notched and joined. The inner surfaces are then hewed off, in such a manner as to make the width at the top 16 inches and at the bottom 8 inches. A rough road must be provided alongside the chute for the team. All grades must be toward the landing, the minimum advisable being about 5 per cent. The more steeper grades there are, the less chute grease and the fewer horses per team will be needed. The maximum grade employed is about 35 per cent. Logs which have been greased above will run on grades over 30 per cent.

A typical chute-building crew consists of five men and a foreman, with two axmen cutting poles and hewing. The daily cost, including stumpage for the fir poles, is approximately $28. Under rather difficult conditions this crew builds 200 feet of chute per day, at a cost of 14 cents per foot. The cost will on the whole range from 10 to 15 cents per linear foot, or from $530 to $795 per mile.

The customary team consists of eight horses. The number of teams required depends upon the length of the chute and the amount of low grade. The logs are yarded into the chute and made into trains of from 6 to 12 logs each. The team is hitched to the last log but one in the train and the last two logs are dogged together.

The amount hauled daily in a representative chute about $1\frac{1}{4}$ miles in length, with two long flats of 5 per cent grade, is about 40,000 feet. Two 8-horse teams, each with a teamster, are required. The rest of the crew consists of a man at the lower end of the chute and two chute greasers, one of whom shovels frogs. The daily cost is about $40. This is a cost of $1 per 1,000, exclusive of maintenance and grease. On another representative chute about 1 mile in length two 8-horse teams handle about 60,000 feet. A driver and greaser are required with each team. The daily cost is about $39, or 65 cents per 1,000. On another chute something over a mile in length with two branches and a steep pitch in the middle, three 8-horse teams are used. One team is used on each branch and the third works between the foot of the steep grade and the landing. The daily cost is approximately $58. At 50,000 feet daily the cost is $1.16 per 1,000; at 60,000 daily it is 96 cents per 1,000.

The cost of keeping up horse chutes and equipment is not high; probably from 5 to 8 cents per 1,000 will suffice. A very considerable cost in many operations is the grease required to make the logs slide in the chute. The heavier the logs and the lighter the grades the more chute grease is necessary. The grease costs about 4 cents per pound delivered, in barrels of about 400 pounds. The heaviest cost of chute grease noted is for the first horse chute described above, which is in fairly large timber. The daily requirement is two barrels, costing $32, or 80 cents per 1,000. Usually for chutes about a mile in length not more than from one-half to one barrel daily is necessary, which would make the cost from 16 to 30 cents per 1,000. On short chutes with favorable grades in light timber the cost of chute grease may not exceed 5 cents per 1,000.

CHUTE HAULING BY DONKEY ENGINES.

Chute-hauling by donkey engines has been a very popular method of moving logs from yard to landing, the tendency having been to reduce the mileage of railroad spurs by a liberal construction of chutes. Firms using donkey chutes extensively laid out their logging operations with railroads along the principal streams and chutes built up on either side to tap the various tributary watersheds. Some loggers still adhere to this system but the majority are eliminating or greatly shortening chutes by better location and greater mileage of logging railroads. So-called hoists or inclines in connection with logging railroads are just beginning to be used advantageously as a substitute for chutes. However, chutes are of value where timber is out of reach of yarding lines either in pockets below the railroad track or on benches or heads of streams above the track, where the cost of constructing a logging spur or incline would be prohibitive.

Improvements.—Most donkey chutes are constructed of two parallel series of poles laid end to end. The ends are jointed together, and the tops of the poles are always placed in the direction the logs are to be hauled. The poles are laid about 6 or 8 inches apart and the inner sides are hewed off in such a way as to form a trough 10 inches wide at the bottom and 30 inches wide at the top. Cross skids at 10-foot intervals are used to support the chute poles across depressions, and braces are used to prevent spreading. However, where the topography permits the two poles are embedded in the ground, which serves the same purpose. Chute poles are preferably 60 or 70 foot lengths from straight young white fir trees. The usual top diameter is 10 or 12 inches, and the average pole scales about 500 feet. Thus, where few cross skids are required, the scale per mile of chute is about 90,000 feet. With a normal amount of cross skids the scale is about 100,000 per mile. Stream beds and small gulches are crossed by means of cribwork trestles, which add varying amounts to the material required.

Some firms prefer wider chutes called "three pole chutes." Two poles are placed much the same as above, but a third pole is embedded in the ground between them. The average diameter of the outside pole is from 14 to 18 inches, and the average diameter of the bottom pole about 8 inches. The width at the top of the hewing is 30 inches; the width at the bottom is 18 inches; and the depth is 8 inches. The scale is about 10,000 feet per mile greater than that for the two-pole type.

Donkey chutes may be constructed on nearly any necessary grade, with the exception that long minus grades of 28 per cent or over are apt to lead to trouble, through the logs running and jumping the chute. The usual grade of downhill chutes varies from 3 or 4 per cent to 20 or 25 per cent. Adverse grades may occur in such chutes up to 10 or 15 per cent. Usually an extra donkey is required at the top of any long or very steep adverse grade. The severest uphill chute noted is one rising 800 feet in 3,900 feet of length (an average of 21 per cent), with 1,200 feet having an average grade of over 40 per cent. The steepest stretch is 500 feet with an average grade of 54 per cent, within which is a 200-foot pitch of 60 per cent.

The best results are secured from chutes constructed on tangents, but curves may be used where it is necessary to change the general direction of the chute. Short curves or reverse curves are out of the question and usually not more than two or three curves are practicable, even in the longest chutes. A change of 90° in the direction of a chute may be made by means of two long and gradual curves.

Typical chute construction crews vary from a foreman and 17 men to a foreman and 22 men. Each commonly has a Dolbeer donkey engine and two horses. The total monthly cost of the former crew is $1,285, and of the latter, $1,600. The latter crew is typical of an extensive chute logging operation and is made up as follows:

1 foreman	$90 and board.	1 line horse driver	$40 and board.
1 engineer	50 and board.	5 axmen	50 and board.
1 fireman	45 and board.	3 shovelmen	40 and board.
1 woodbuck	40 and board.	1 grading boss	75 and board.
1 waterbuck	40 and board.	5 muckers	40 and board.
2 swampers	50 and board.	1 line horse.	
1 lookout	50 and board.	1 water horse.	

The cost per mile of construction depends upon the configuration of the ground and the accessibility of suitable chute timber. Except for short spurs, the cost varies from about 20 cents per linear foot under favorable conditions to 40 cents per foot for difficult. Construction in open stands, with no rocks and with a fair supply of chute timber, costs, exclusive of stumpage, about $1,000 per mile, of which amount $350 is for clearing and grading. Heavier grading, with some rockwork but no trestles, costs about $1,400 per mile.

A chute with heavy grading and a small amount of trestlework costs about \$1,500 or \$1,600 per mile. A chute with one large trestle or three or four moderate trestles costs about \$1,800 per mile. A combination of large trestles and heavy grading may make a chute cost from \$2,000 to \$2,200 per mile. The average allowance for the cost of chutes for good-sized logging chances should be from \$1,300 to \$1,400 per mile for good conditions; from \$1,500 to \$1,600 for fair conditions; and \$1,800 for very difficult conditions. Chute landings cost from \$50 to \$100 each.

Equipment.—The donkey engines used for chute hauling are commonly larger than those used for yarding. They are of the wide-drummed type usually described as roaders. The size varies with the difficulty and length of the haul. For short downhill pulls a 10 by 12 inch engine may be satisfactory. On the other hand, for steep uphill pulls or very long hauls a 12 by 14 inch or even a 14 by 14 inch roader may be used.

The f. o. b. factory cost of representative roading engines is approximately from \$2,650 to \$5,450.

TABLE 6.—*Factory cost of representative roading engines.*

Size.	Weight.	Cost.
Inches.	*Pounds.*	
12 by 14	46,000	\$4,650
14 by 14	58,000	5,450
11 by 14	36,300	3,450
12 by 12	36,500	3,500
13 by 14	45,200	4,350
10 by 12	27,000	2,650
11 by 13	38,000	3,650
12 by 12	40,000	3,800
Size.	**Main line, 1¼-inch cable.**	**Back line, ⅝-inch cable.**
Inches.	*Feet.*	*Feet.*
11 by 13	4,080	10,600
12 by 12	4,070	9,850
12 by 14	5,100	13,850
14 by 14	8,100	21,400

The prices of smaller machines and the approximate cost of placing the engines on the ground are given under the discussion of donkey yarding equipment.

The size of the cable used for chute hauling depends upon the severity of the haul. For light downhill pulls 1-inch or 1⅛-inch main line may be used. The standard size for long and uphill hauls is 1¼-inch main line, and the usual back line is ⅝-inch. The cost is given under donkey yarding equipment. The cable capacity of representative roaders is shown in Table 6.

On the main line of a chute ground rollers are placed at intervals, and corrugated rollers, mounted on so-called dead-men, are required

at curves. Corrugated rollers 8 inches in diameter and 12 inches long are listed at $9 each, and ground rollers 4 inches in diameter and 12 inches in length at $4.50 each. Trip-line blocks similar to those used in yarding are required for the back line, and a large tailblock is placed at the outer end of the line.

Operation.—The bull donkey or roader is stationed at the landing on the logging railroad. A second roader or swing bull may be located farther out along a chute which is very long, crosses over a ridge, or has as many as five yarders. Each bull donkey has a separate crew and main and back lines. The line from the donkey at the landing extends only as far as the swing donkey.

The yarding donkeys are stationed at various points along the chute, usually moving farther out as each setting is completed. A so-called frog is built in the chute at each yarder setting, and the logs are pulled into the chute by the yarder. When several yarders are working on a chute, a branch must be built at each setting for making up trails. If the timber is logged in long lengths, the steam-saw bucking is done in the chute at the yarder.

When enough logs are collected in the chute at a yarder to make a trail, the last two logs are dogged together and the outer end of the main line is attached to the next to the last log. Either double chain-grab hooks or a choker are used for this purpose. The latter is preferred for difficult hauls. The trail of logs is then pulled into the landing. The size of the trail depends upon the grade of the chute and the size of the donkey. For downhill hauls the trail usually contains from 10 to 16 logs, or from 5,000 to 7,000 board feet. On a very heavy uphill the average trail is from seven to nine logs, or from 4,000 to 5,000 feet. The heavier donkeys now being introduced should handle larger trails on downhill chutes.

As a general rule, the more yarders on a chute, the cheaper the hauling. Some firms, usually those using chutes infrequently, place but one yarder on a chute and thereby incur an unnecessarily heavy cost for chute hauling. The only excuse for such a layout is a very short chute with only one or two settings on it. On a downhill chute under 4,000 feet in length with a yarder averaging about 30,000 feet b. m. daily, the crew is as follows: One lineman, 1 bellhop, 1 engineer, and 1 fireman. The bellhop does what greasing is necessary and the lineman does the dogging. Only six trips need to be made daily, which allows considerable time for resting. The daily labor cost is about $12.80. Wood is furnished by one man and a horse, and water is pumped to both machines. Exclusive of cables and chute grease, the average cost per 1,000 feet is about as follows: Operation, 43 cents; fuel, 11 cents; water, 6 cents; maintenance, 12 cents; total, 72 cents per 1,000.

There should be at least two yarders upon a chute from 2,000 to 4,000 feet in length. The crew is larger than that given above by one greaser and one dogger, increasing the daily labor expense by \$5. Assuming that the yarders average 30,000 daily, the cost per 1,000 is as follows: Operation, 30 cents; fuel, 8 cents; water, 4 cents; maintenance, 10 cents; total, 52 cents.

The most economical chute hauling occurs where three yarders are located upon one chute with one bull donkey. This is rarely done, and such yarders usually do not average over 25,000 daily. The crew contains one greaser and three doggers in addition to the number for one yarder. The daily labor expense is \$23.30. The cost per 1,000 is accordingly estimated as follows: Operation, 31 cents; fuel, 5 cents; water, 3 cents; maintenance, 8 cents; total, 47 cents per 1,000.

On extensive operations, where the chutes are a mile or more in length and have several branches, it is customary to place two bull donkeys and either four or five small yarders upon each chute. The minimum daily output from such a chute is usually about 110,000 and the maximum 130,000. The crew required is 2 linemen, 2 bell-hops, 4 or 5 doggers, 2 greasers, 2 shovelers, 2 engineers, and 2 firemen. Three men and two horses are required to supply fuel, at a daily cost of \$9.25. The daily labor cost for an output of 110,000 is about \$47.25. The cost per 1,000 is approximately as follows: Operation, 43 cents; fuel, 8 cents; water, 5 cents; maintenance, 10 cents; total, 66 cents per 1,000. The cost for a daily output of 130,000 is as follows: Operation, 38 cents; fuel, 7 cents; water, 4 cents; maintenance, 8 cents; total, 57 cents per 1,000.

The cost per 1,000 board feet of the cables used varies with the length of the haul. Under average working conditions 1¼-inch main line and ⅝-inch back line last two full seasons. If the work is light, they should last a season longer. Thus for chutes from 3,000 to 4,000 feet in length with two yarders averaging 30,000 each daily, the cable cost is about 13 cents per 1,000. For a chute over a mile in length with two bull donkeys and an average daily output of 120,000, the cable cost is about 11 cents per 1,000.

In order to overcome friction, portions of the chutes having low or adverse grades are greased with so-called chute grease (crude petroleum). The brand commonly used is sold at 2¼ cents per pound f. o. b. San Francisco. It usually costs about one-half cent per pound more in the woods. A barrel contains approximately 400 pounds and costs about \$11 delivered. The amount used depends upon the amount of unfavorable grades. A chute about 5,000 feet in length, of which about one-quarter is upgrade at not to exceed 10 per cent, requires one barrel of grease every three days. The

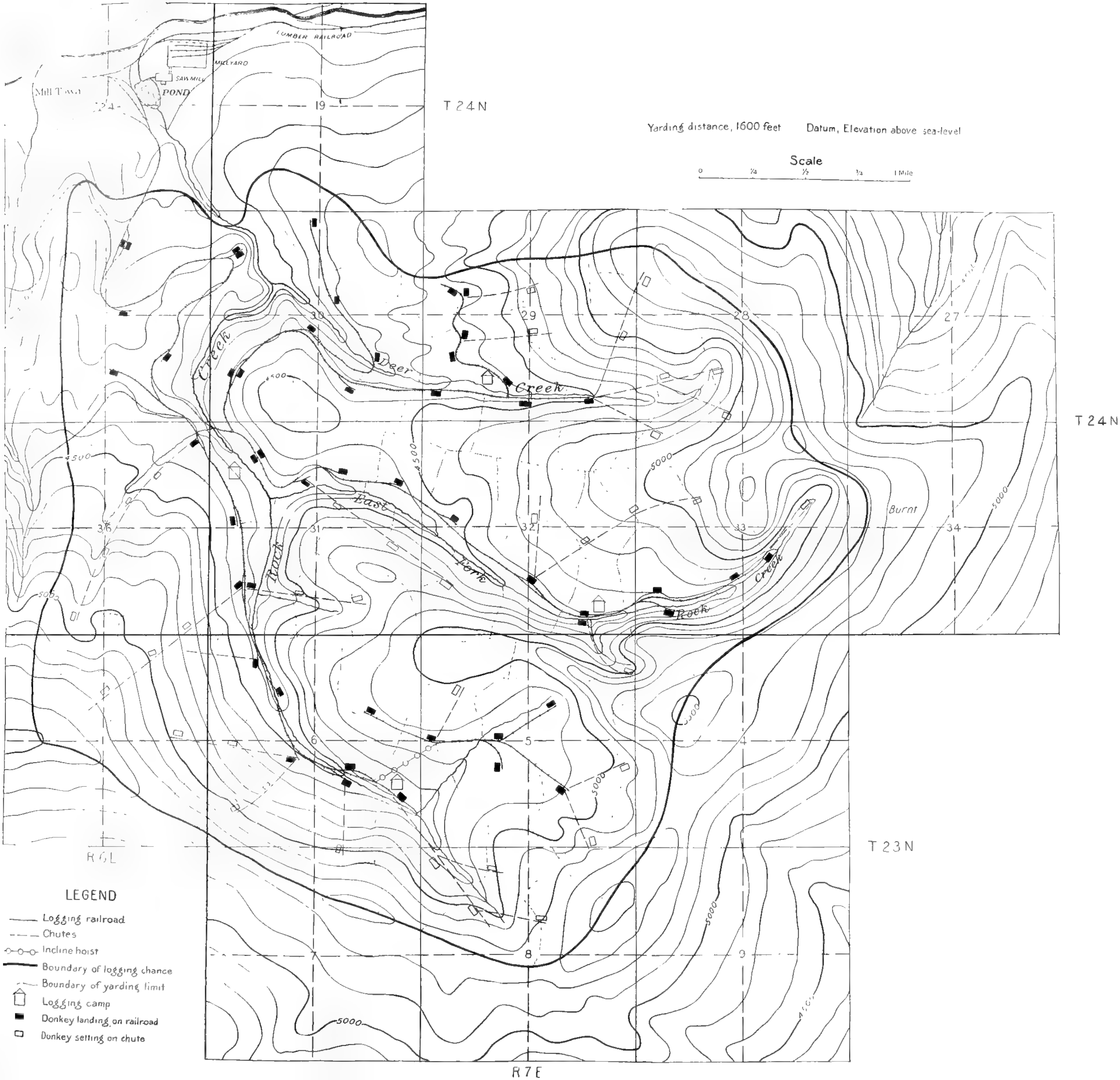


FIG. 1.—REPRESENTATIVE LAYOUT OF RAILROAD AND CHUTE LOGGING OPERATION, SUGAR AND YELLOW PINE REGION OF CALIFORNIA.

average amount hauled daily is 110,000 and the cost for grease about 4 cents per 1,000. On the other hand, a chute 4,000 feet long, with an average adverse grade of 21 per cent and one pitch of 60 per cent, requires four-fifths of a barrel daily for an output of 50,000. The cost is about 14 cents per 1,000. An allowance of 5 cents per 1,000 for chute grease is ample for most chute logging in this region.

DONKEY ENGINE ROADING.

Roading with donkeys on dirt roads is rare, and when used is really a form of double yarding. It is sometimes employed to reach a body of timber too far away for single yarding but not large enough to warrant the construction of a spur or chute. A yarder is placed in the timber and a roading engine stationed at the nearest landing to haul the logs from the yarder to the track. The logs are hauled in the same manner as they are yarded, either singly or two abreast. One roader can serve but a single yarder and the cost is similar to yarding except that the crew is smaller.

A representative roader hauling 30,000 daily, a distance of from 1,600 to 2,000 feet, requires a crew of an engineer, fireman, lineman, blocktender, and whistlepunk. The daily labor cost is $15, or 50 cents per 1,000. Fuel and water cost about $5 per day, maintenance of donkey and tools about 16 cents per 1,000, and cable maintenance about 12 cents per 1,000. The total cost under the conditions given is approximately 94 cents per 1,000.

FROM LANDING TO MILL.

LOADING.

Logs are sent to the mill on log cars, or on trucks, either horse or traction hauled. In general, the operation of loading is the same for trucks as for cars. The simplest method is by hand. It requires small logs and a high landing. This method is infrequently used for loading on railroad cars at the lower end of a chute. In timber averaging five logs per 1,000, six men with peavies may average 50,000 daily at an average cost of 33 cents per 1,000. The only equipment needed is the peavies, which cost about $18 per dozen.

The system of loading termed the "crosshaul" is widely used in truck logging, and sometimes for loading cars. The logs are rolled up skids and onto the truck by means of a chain or cable pulled by a team on the opposite side of the truck. The free end of the cable is fastened to the truck or to the load by a hook and the log is rolled up in the bight. In truck logging the loading is usually done by the truck teamster with a pair of leaders or by the bunch teamster with the bunching team. Thus it is rather difficult to separate the cost from that of bunching or of truck hauling. Ordinarily, for moderate sized logs this cost should be about 30 or 35 cents per 1,000. This system is used in one instance under favorable conditions with a

daily output of from 30,000 to 35,000. A crew of one teamster, two loaders, and a team is required, at a daily cost of $10. Besides the horses, harness, and spreaders, the only equipment needed is two peavies for the loaders and 80 feet of loading cable costing about $7.

The most widely used method is by cable and "gin pole." It seems best adapted to donkey logging, and is also used for loading traction trucks. A gin pole, consisting of a log from 14 to 18 inches in diameter by 40 feet high, is erected on the opposite side of the track from the landing and guyed with five cables in such a manner that the upper end is over the center of the track. A block is fastened at the top of the gin pole and a three-fourths inch loading cable passes through it from the loading drum of the engine. This cable may terminate in a hook and be used in much the same manner as the cross-haul, or it may terminate in a crotch line with two end hooks.

Upon one traction logging operation where the loading is done at the lower end of a horse chute, the gin-pole system is used, power being furnished by a Dolbeer donkey engine. The crew consists of 1 engineer, 1 spool tender, 2 loaders, and 1 waterbuck, with a combined labor cost of $14.40 per day. The average daily output is 60,000 and the average cost 24 cents per 1,000. This should probably be increased by 2 cents per 1,000 for maintenance of the donkey and other equipment.

The gin-pole system is widely used where yarders are located at landings along logging spurs. The best results are obtained with cables terminating in a crotch line. The logs are lifted bodily in the air and lowered in place upon the car. Motive power is commonly furnished by a loading spool or a third drum upon the yarder. The crew consists of a spool tender and two loaders, and the total daily cost is $9. Such a crew is ample to handle the output of any yarder; and usually no matter how small the daily output there can be no reduction in the number of the crew. Thus the cost of loading depends primarily upon the average daily output of the yarder. The cost is as follows, according to the daily output: 25,000, 36 cents; 30,000, 30 cents; 35,000, 26 cents; 40,000, 23 cents per 1,000 feet.

The cost of loading by this system at chute landings is cheaper than when each yarder is at a separate landing on the railroad. The reason is that, from two to five yarders being stationed upon a given chute, logs are delivered in quantity up to the maximum capacity of the outfit. The loading crew is the same as at a yarder, except that for a daily output of 120,000 it must be enlarged by one top loader, one loader, and one shoveler. The daily labor cost is therefore about $18.50 per day, or 15 cents per 1,000. At 100,000 daily the cost is about 19 cents per 1,000.

A separate loading engine is probably better as a motive power than a spool or drum upon the logging donkey. It may be either a

winch operated by steam from the donkey boiler or a separate engine and boiler. The advantage of the separate engine is that yarding or chute hauling need not be interfered with to favor loading. Further, when a separate boiler is used, loading does not lower the steam in the donkey boiler. The crew and labor costs are the same with a separate loading engine as with a loading spool. Probably from 2 to 4 cents per 1,000 should be added for maintenance; but this extra cost is undoubtedly more than offset by increased efficiency in yarding. A $7\frac{1}{4}$ by 10 inch three drum loading donkey weighing 11,000 pounds costs $1,550 f. o. b. factory. A $6\frac{1}{2}$ by 8 inch twin drum loading engine weighing about 7,000 pounds costs about $1,000 f. o. b. factory.

One firm uses $6\frac{1}{2}$ by 8 inch loading engines at each yarder or chute donkey. The loading engines are placed on a platform on the opposite side of the track from the landing and the loading is done by means of a short cable exactly as in the horse crosshaul. The crew and cost is approximately the same as given above under the gin-pole system. Another style of loading, used by one large operator in this region, is a crotch line supported by an A frame placed on the front ends of the donkey skids. This A frame is primarily for supporting the yarding line and is obviously modeled upon the principle of the steam skidders. No landings are needed, but loading is difficult, dangerous to employees, and interferes to a certain extent with yarding. The loading crew is the same as that employed at each yarder by the gin-pole system.

Special log-loading machines have not yet proved satisfactory in this region in connection with donkey logging, the cost being higher than if a gin pole were employed. They are, however, very efficient in big-wheel logging operations, for use in loading from log decks, for transferring logs from one car to another, and for picking up logs along the railroad right of way. The type generally used is a self-propelling loader having an inclosed raised platform upon which is located a donkey engine and loading drums. When loading the trucks are raised up and the machine rests on four supports, thus giving room for the empty cars to pass underneath. The loading is done by a cable and crotch line passing through a block at the end of a boom. This boom is in the form of an A frame and may be either rigid or swinging. The cost ranges from $5,500 to $7,500 each. The daily capacity varies from 120,000 to 150,000, depending upon the chance and the size of the logs. It is usually found practicable in large big-wheel operations to deliver from 100,000 to 120,000 daily at each loader. At one representative operation the crew consists of 1 engineer, 1 fireman, 1 woodbuck, 1 top loader, 1 second loader, and 2 hookers, the total daily cost being $19.10. Water is supplied in a

tank car at a cost of $3.50 daily. The cost of loading, therefore, averages about 21 cents per 1,000. To this amount should be added 2 cents per 1,000 for maintenance of the machine.

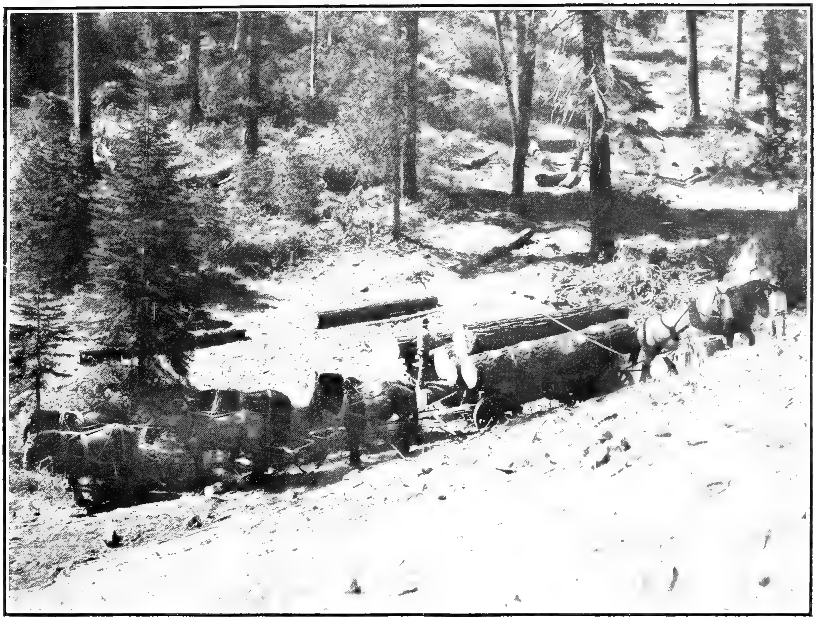
HORSE TRUCK HAULING.

Horse truck hauling is much used at the smaller mills. Where conditions are favorable the trucks may be taken to each tree and the logs loaded with the truck team. In rougher localities the logs are collected at landings by horse skidding or hauling in chutes. Horse trucking permits a rather small woods investment, which adapts it to small operators. Its use is limited to localities where truck roads with moderate grades can be constructed at a reasonable cost. In the level regions big wheels are considered more satisfactory for short hauls.

Except in some of the level pine lands in the eastern Sierras, a road must be constructed to each landing for truck hauling. Such roads should have no adverse grades against the loaded trucks, and not too heavy ones against the empty trucks. Probably 20 per cent is a good maximum. Pitches as high as from 30 to 35 per cent are used in some localities, but at a heavy risk of accidents to stock. Many of the roads are constructed by simply swamping out a right of way and driving over it. However, whenever it is necessary to cross a slope a road must be dug out. Except where solid rock is encountered, the cost of such grading will be about 15 cents per cubic yard. Upon a 20 per cent slope the cost per mile is estimated at from $500 to $700.

The trucks used are of heavy construction, and are usually partly homemade. Frequently the wheels are cross sections of a log. The tires are usually 5 or 6 inches wide. The four-wheeled type is the only kind used. They weigh from 1,800 to 2,000 pounds apiece and cost from $175 to $200, fitted with bunks. Binding chain and draft chain equipment and spreaders add about $40 for each truck. Heavy horses cost from $500 to $550 per span. The daily cost is about $1.50 each. The usual truck team consists of six horses driven with a jerk line, the teamster riding the near wheeler. The braking may be done by the teamster, or a swamper may follow each truck to set the brake.

Several logs are placed on a truck at one time. the average load being from 1,400 to 1,800 feet. Upon an easy mile haul a six-horse truck should make six trips daily with an average load of 1,500 feet, a daily output of 9,000. The cost of labor and team expense is about $13.50 daily, or $1.50 per 1,000. On a ½-mile haul the same truck equipment should have a daily output of about 12,000 at an average cost of $1.12 per 1,000. In one instance, upon a haul varying from 1 to 2 miles from the landings to the mill, six outfits of this character



F-95311

FIG. 1.—LOADING LOGS WITH A CROSSHAUL IN A HORSE-TRUCK LOGGING OPERATION.

F-95301

FIG. 2.—LOADING LOGS WITH A SPECIAL LOADER ON A NATIONAL FOREST TIMBER SALE IN CALIFORNIA.

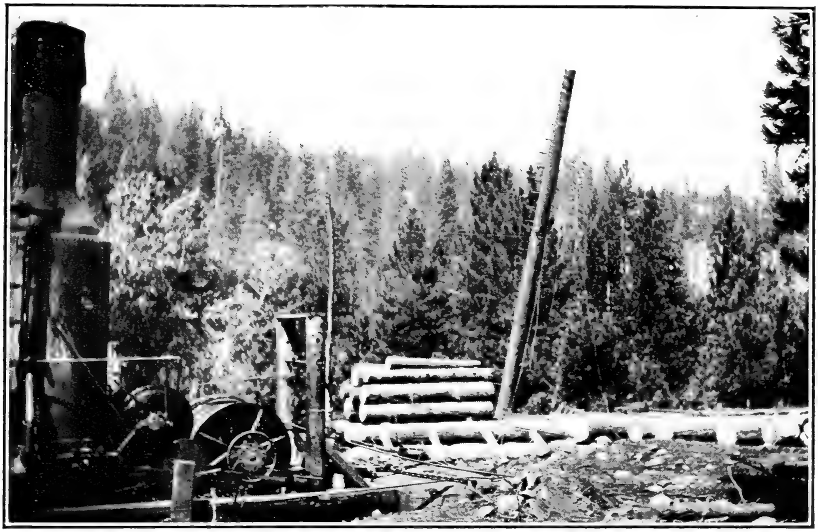


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FIG. 1.—TYPICAL LANDING AND GIN-POLE USED FOR LOADING IN THE SUGAR PINE REGION.

F-12791-A

FIG. 2.—TRUCKS LOADED WITH LOGS READY FOR HAULING WITH A TRACTION ENGINE.

average 40,000 per day. Four trips are made with an average load of between 1,600 and 1,700 feet. The daily cost is about $80, or $2 per 1,000. The cost of upkeep ranges from 8 to 12 cents per 1,000.

TRUCK HAULING WITH TRACTION ENGINES.

Truck hauling with traction engines is used at some small circular mills and at one single-band mill in this region. It does not require any outlay for track, but this is often more than offset by the impossibility of using the engines in wet weather. A rainy summer season will raise havoc with such a logging operation. On the whole, tractions are adapted to truck hauls too long for horses.

The roads required are like those used for horse hauling, except that the roadbed is wider. The cost is consequently greater. Upon a 20 per cent slope the cost of construction, excepting rockwork, is from $625 to $875 per mile. Damp or soft places must be corduroyed with poles.

A common type of traction engine in use for logging is a 110 horsepower road engine, which costs about $5,000 f. o. b. factory. The fuel may be either wood or oil. The boiler is vertical in order that the engine may be used on heavy grades. The weight of the engine is about 17 tons. The outside width of the driving wheels is 9 feet 7 inches, and the width of each wheel is 26 inches. Another engine used is a gasoline engine of the caterpillar type, designed for soft ground. The cost of this 75-horsepower tractor is about $4,500 f. o. b. factory. Its weight is 22,700 pounds and its width is 8 feet.

Two kinds of trucks are used with traction engines. One is four wheeled with either wooden or steel wheels. The common size has bunks 9 feet wide, spaced 10 feet apart center to center. The wheels are 4 feet 4 inches in diameter and the outside tread is 7 feet. One of these trucks with steel wheels costs about $800 f. o. b. factory. The other type is of all steel construction and has only three wheels, one in the middle at the front. It is rated at 10 tons capacity, as against 16 tons capacity for the four-wheeled trucks.

A typical traction logging operation furnishes logs for a single-band mill in the eastern Sierras. The length of the haul varies from 2½ to 3 miles. The maximum adverse grade loaded is 2 per cent; and empty, 14 per cent. Two wood-burning traction engines make two trips each daily with three four-wheeled trucks. The average truck load is 5,000 feet of logs, a daily output of 60,000. The crew of each engine consists of one engineer, one fireman, and one brakeman, at a daily cost of $14.25. Approximately 4 cords of slabwood are required daily per engine. A cord is worth about $2 per 1,000 at the mill, making a total fuel cost of $16 per day for both engines. Oil and grease amount to $1.10 daily per engine. Repairs to engines and

trucks for both outfits, including blacksmithing and supply expenses, amount to about $10 daily. The total daily cost is $56.70, or about 94 cents per 1,000. This does not include road repairs.

LOGGING RAILROADS.

Steam logging railroads are the principal means of transporting logs from the woods to the mill. These all have steel rails, there being no pole roads or sawn wooden rails used. The principal reason for the wide use of railroads in logging in California is length of haul. Much of the pine timber is at a considerable distance from trunk line railroads, and heavy investments are required in lumber railroads or flumes. Large mills and heavy output are necessary to warrant these investments. In turn, large mill outputs require extensive logging operations, which necessitate long log hauls. The general topography of the region is rough and mountainous and the logs are too heavy to be handled except by steam. Stream driving is practically out of the question, both because the streams are rocky and difficult of improvement and because sugar-pine and white-fir butt logs will not float. Thus logging railroads are a necessity in practically all operations of any size.

Engineering.—The location of the logging railroad and its spurs is the most important part of the layout of an operation. The type of railroad and the route selected depend upon the period the railroad is to be operated and the amount of timber. The expense of construction should be the least that will serve the purpose required and at the same time permit of a reasonable cost of operation and maintenance. The longer a road is to be used and the heavier the traffic, the better it can be constructed. Logging railroads are constructed more cheaply than even branch trunk line railroads, because the period of operation is shorter. Heavier grades, sharper curves, and poorer roadbed may be used.

Topography is the principal factor influencing the location of logging railroads; but the general plan of logging determines whether they, especially branch lines, shall follow valleys, ridge faces, or the tops of ridges. One reason why the railroad layout for steam yarding differs from that for yarding by horses is that on steep ground yarding engines work more satisfactorily uphill. Main lines are necessarily located and constructed with greater care than spurs. Spurs are constructed wherever they are necessary to bring timber within chuting or yarding distance of the main track. The mileage depends upon the topography, maximum yarding distance, amount of chute hauling, and density of the stand.

In chute logging the main line railroads are constructed along the streams, and chutes are relied upon to bring the timber down to them. Spurs are constructed only to reach chute landings which can not be

placed on the main line. The better layout, and one now coming into general use, is to locate the logging railroads on the faces of the slopes and eliminate chutes as much as possible. A large part of the yarding can thus be done directly to the main line. Spurs are constructed to within yarding distance of the remaining timber. Chutes are used only to tap inaccessible coves where the amount of timber will not warrant a spur.

Although it is ordinarily good economy to construct spurs as above, the mileage obviously must not be increased to a point where the saving in yarding is more than offset by the added cost of spurs. For big-wheel yarding, spurs should be placed within one-quarter mile of all timber. For donkey yarding, with favorable conditions for railroad building, the maximum distance from the stump to the track should be from 1,400 to 1,500 feet. Where railroad construction is more difficult, the outside distance should be 2,000 feet, with a usual maximum of 1,600 feet. Usually in locating spurs, the proper settings for the yarding engines are selected and the spur laid out to reach these settings.

Switchbacks are frequently used in order to climb elevations where otherwise the grade would be too steep. As many as four switchbacks are sometimes used in laying out a single spur. Where the rise is considerable, a log hoist or an incline is often cheaper than switchbacks or detours.

There are two gauges used generally for logging roads in this region; narrow gauge, 36 inches in width, and standard gauge, 56½ inches in width. One exception is a road with a width of 1 meter. Narrow-gauge roads can be constructed for less than standard gauge, and the equipment is lighter and less expensive.

The standard gauge is preferred by most operators because a larger tonnage can be handled at a lower cost for operation and maintenance. One of its greatest advantages is that standard equipment, such as trunk-line cars, can be hauled on it. This is of great importance where the logging road connects with common-carrier railroads, because supplies and horse feed can be delivered at the camps in the original cars and any product, such as cordwood or posts, can be loaded for shipment on standard cars.

The narrow gauge is preferred in very rough country, because sharper curves are permissible, less width of roadbed is required, and the construction cost is less. Further, in small or short-time operations the investment for a narrow-gauge railroad and equipment is all that is justified. If a narrow gauge is selected as the proper type all logging railroads on the operation should be of the same gauge.

The maximum grades and curvature allowable on a logging railroad vary with the character of the line and the type of locomotive.

Grades and curvature may be heavier on spurs than on the main line where heavier loads must be handled. A geared engine can negotiate heavier grades and sharper curves than a rod engine. Narrow-gauge equipment can follow sharper curves than standard.

Except where topographic conditions forbid, long main-line logging railroads are usually constructed to permit the use of rod engines. The maximum grades allowed are 3 or sometimes 4 per cent empty and 1 per cent loaded. The sharpest curves are usually 16° for standard gauge and 20° for narrow gauge.[1] In rougher regions even main lines can not be constructed for rod engines at a reasonable cost and geared engines must be used. The maximum grades ordinarily employed are 5 per cent empty and 2 per cent loaded. A heavier grade than 5 per cent can be surmounted, but it is difficult to hold a heavy train on the down grade. The maximum curves used are from 25° to 30° for standard gauge and from 30° to 40° for narrow gauge.

Logging spurs are usually constructed for the use of geared engines with a few cars at a time. The usual maximum grade for empties is 7 or 8 per cent, or even 10 per cent on short pitches, and the maximum for loads about 4½ per cent. The usual maximum curve for narrow-gauge spurs is 50°, though in some instances curves as sharp as 60° are used. The maximum for standard gauge is about 40°. One company using saddle-tank dinkey rod locomotives with a wheel base of 8 feet constructs its narrow-gauge logging spurs with maximum grades of 5 per cent empty and 2 per cent loaded and a maximum curvature of 50°. The maximum grades given above are of course compensated on curves at the rate of from 0.02 to 0.03 per cent per degree.

All of the larger companies employ competent woods engineers to lay out their railroads. The engineers cooperate with the woods superintendent in determining roughly the routes of main-line extensions and spurs. The engineering force then makes preliminary and permanent location surveys and exercises general supervision over the construction. Upon the larger operations the engineer has a crew of a transitman and two helpers. The engineer is usually employed the year round and devotes his time in winter to mapping and cruising. During the summer considerable time of the engineering force is devoted to running land lines and other activities apart from railroad construction. The cost of engineering upon logging railroads varies from $200 to $400 per mile for main lines, depending upon the difficulty, and from $125 to $250 per mile for spurs. In the construction of commercial railroads it is usually customary to figure engineering as 5 per cent of the other costs.

[1] Straight connected saddle-tank locomotives with a short wheel base can be operated over sharper curves than these.

Construction.—The first step in railroad construction, following the final survey, is the clearing of the right of way by felling all trees and cutting out all brush and reproduction. The usual clearing crew is two men, who, under ordinary conditions, clear from 1 to 1½ miles of narrow-gauge right of way per month. Saws and axes are used for felling and swamping, and after the trees are felled the butt logs are bucked off and rolled outside the right of way with jackscrews.

In ordinary sugar and yellow pine stands the cost of clearing the right of way ranges from $40 to $45 per acre. The average width of clearing for a narrow-gauge road is from 20 feet for flat country to 30 feet in broken country. The former is about 2½ acres per mile and the latter about 3¾. Under like conditions the clearing for a standard-gauge road may be 5 or 10 feet wider. The cost for a narrow-gauge right of way is ordinarily from $100 to $160 per mile, and for a standard-gauge from $125 to $200 per mile.

Before grading is commenced all stumps which will interfere with excavation for the roadbed must be removed. This is usually done by blasting with 5 per cent blasting powder. An iron bar is driven under each stump and a small piece of giant powder exploded at the bottom of the hole. The cavity thus formed is loaded with blasting powder, and the explosion of this charge blows out the stump. Average loads are one-fourth box (12½ pounds) for a 12 to 16 inch stump, 1 box for a 30 to 36 inch stump, and from 2 to 2½ boxes for a 60-inch stump. Yellow pine is the most difficult to blast out and sugar pine and incense cedar the easiest in about the ratio of 1¼ boxes for a 30-inch yellow pine to three-fourths box for a 30-inch incense cedar.

Blasting powder comes in 50-pound boxes, which cost from $3.25 to $3.75 each delivered on the works. Counting in a man's labor for from one to two hours, caps, a stick and a half of giant powder, and the necessary fuse, the cost of removing a 36-inch pine stump is from $4 to $5. The cost of blasting stumps per mile varies with the species, number, and size of the stumps. In normal sugar and yellow pine stands it averages from $200 to $250 per mile, respectively, for narrow and standard gauge. Some miles run as high as $400 each.

When the stumps have been removed the right of way is ready for the grading of the roadbed. The width of the roadbed varies from 11 to 12 feet for narrow gauge and from 13 to 14 feet for standard gauge. Sidehill cuts are commonly made in such a manner that two-thirds of the width of the roadbed is a solid cut and the remainder a fill. In most cuts the sides are sloped at one-half to one, which is the equivalent of a horizontal distance of 6 inches to a vertical distance of 1 foot. In very soft soil it may be necessary to use a slope

of one to one. The usual slope for an earth fill is one and one-half to one for most soils encountered in railroad building in this region.

Most of the grading is done with pick and shovel. This is particularly true of sidehill work where the bank may be picked away and shoveled to the lower side. Light work on fairly level ground is done in the same way, the dirt being borrowed from ditches or borrow pits. Frequently moderate sized cuts and fills, under favorable soil conditions, are handled in the same manner, the material from the cuts being mostly wasted and that needed for fills borrowed.

Pick and shovel work is usually done by day labor, as are all other parts of railroad construction. As a rule the men work in crews without any particular task for each. Very good results are secured, however, by assigning each man to a 25-foot station. This promotes rivalry, as the men do not like to be left behind when their neighbors have finished and gone ahead. The cost of digging and spreading dirt is commonly from 15 to 25 cents per yard for common loam, and from 30 to 35 cents for heavy soils.

In larger cuts the dirt is moved to adjacent fills with wheelbarrows. Even better success is secured by using light two-wheeled hand dump carts holding from one-third to one-half yard. Three men handle each cart, first filling it and then wheeling it out to the fill. Planks are laid in the bottom of the cut to facilitate wheeling. The cost of such work, where rocks are not encountered, ranges from 30 to 50 cents per yard. In very large cuts it is sometimes the practice to lay a temporary track and remove the dirt by shoveling it by hand onto a train of flat cars, which is hauled out on the line by an engine, the dirt being used for ballast.

A typical pick and shovel crew consisting of a foreman, a blacksmith, a man with a team and wagon, and 44 muckers, costs $2,500 per month. Working under rather favorable conditions, with soil that is easily worked and a moderate amount of soft rock, this crew grades about 85 stations per month, the average amount of material moved per station being about 60 yards. This is done at a cost of $1,560 per mile, or 49 cents per yard.

Many firms supplement the pick and shovel crew by a second crew, using teams and scrapers for grading the larger cuts and fills. A typical crew of this sort contains a foreman, 3 teamsters, 3 men holding slips, 5 muckers, and 3 two-mule teams. The cost is about $3.20 per hour, and earthwork can be done for from 20 to 25 cents per yard for distances not over 100 feet. So-called slips are used to scrape up and transport the dirt after it has been loosened by the muckers with picks. Wheeled scrapers are rarely used. In some instances ordinary one-horse dump carts are employed with success for moving dirt some distance. Steam shovels are infrequently used in cuts on extensive main line roads, usually lumber roads rather than

logging roads. Steam shovels may also be put to good use in loading gravel for ballast. A 1½-yard dipper steam shovel suitable for heavy work costs $8,060 at San Francisco. A smaller revolving shovel with a seven-eighth-yard dipper costs $5,640.

Solid rock and loose rock that can not be loosened with a pick must be broken up by blasting before excavation. Hand drills are used in making the required shot holes. These holes are loaded with sticks of high-grade giant powder, costing 11 or 12 cents per pound, and the charges exploded by caps and fuse. Soft rock and decomposed granite are often blasted more effectively by loading burrows with large quantities of low-grade powder, such as is used for removing stumps.

Average costs may be calculated by classifying the material to be moved. Light earthwork on spurs and in smooth regions can usually be done at an average cost of from 15 to 25 cents per cubic yard in place. Heavier dirt work will average from 30 to 40 cents per yard. Ordinary earthwork with a moderate amount of soft rock averages from 40 to 50 cents per yard. The cost of grading with a normal amount of rock ordinarily averages from 50 to 60 cents per yard. Most of the logging roads on the west slope of the Sierras are graded at this average cost. Soft rock requires an expenditure of about 75 cents per yard and removing solid rock costs $1 or more per yard.

The easiest grading occurs in the flat sugar and yellow pine stands of the northeastern part of the State, where the average cost for standard-gauge spurs is often about $800 per mile. Some miles are graded for as low as $200 or $300. The next cheapest work is in the yellow pine of the eastern Sierras, where, in moderately rolling regions, the average cost is from $900 to $1,000 per mile. For the easier grading in moderately rough regions on the west side of the Sierras, where about from 50 to 70 yards are removed per station, the cost is from $1,500 to $2,000 per mile. The average cost in this part of the region for fairly rough localities is from $3,000 to $4,000 per mile. The steeper and rougher regions necessitate an average grading cost of from $5,000 to $5,500, and on some lines the cost may be as high as $7,000 per mile. An unusually large amount of rock-work runs the cost of some miles up to $12,000. For most of the sugar pine stands the average cost of grading main lines and spurs is betweeen $3,500 and $5,000 per mile. The cost of grading a narrow-gauge roadbed is from 10 to 20 per cent less than a standard gauge.

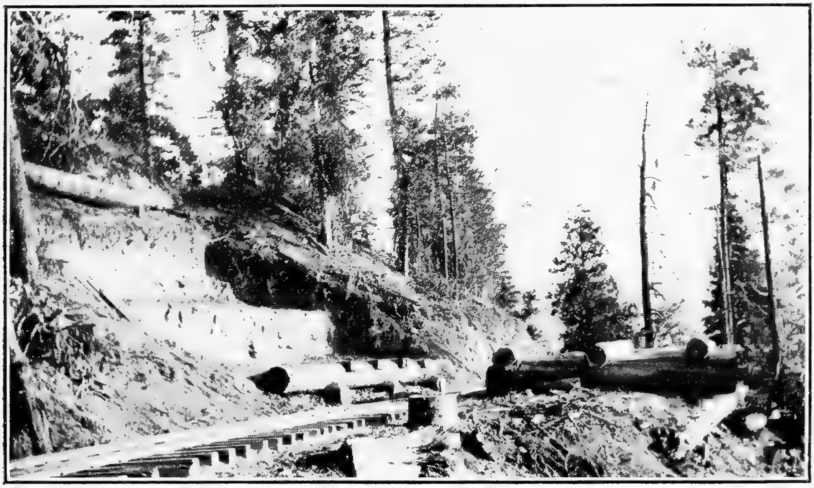
For temporary lines it is frequently cheaper to construct cribbings or trestles than fills. Cribbings are used in shallow depressions, and consist of large logs laid at right angles to the track 12 feet apart from center to center, Two other logs are laid lengthwise on these for stringers. The cost for an average height of from 4½ to 5 feet is

from 50 to 60 cents per linear foot, exclusive of stumpage. From 400,000 to 450,000 feet board measure of logs are required per mile.

Two types of frame trestles are in use on logging railroads, namely, rough timber and sawed timber trestles. Rough timber is usually used on spurs or lines which will be in use for a short time only, because it decays more quickly than sawed timber. Its durability is increased, however, by peeling the poles. Where suitable pole timber is available, a rough timber trestle can be constructed more cheaply than one with a sawed frame. Rough timber trestles are commonly built with bents 15 feet apart from center to center. Each bent contains a log for a sill and four smaller logs for posts. Rough timbers are used for caps and stringers, but the bracing is done with sawed 3 by 8 inch planks. The usual method of building such a trestle is to place a Dolbeer donkey at the site and skid the sills, posts, and caps in from the near-by timber. The bents are then built on the ground and raised to a vertical position by the donkey engine. In one instance a crew of 18 men working in this manner constructed a standard-gauge rough timber trestle 255 feet long, with a maximum height of 38 feet in eight working days, at a labor and supply cost of $416. The log scale of the material involved was as follows: Caps, 2,700 feet; stringers, 6,900 feet; posts, 9,420 feet; sills, 10,400 feet; total, 29,420 feet. In addition, 4,800 feet of braces were required. Allowing $1 per 1,000 stumpage on the rough timber and $12 per 1,000 as the cost of braces, the total cost is $503. Thus, for this example, the cost per 1,000 is $14.80, and the cost per linear foot is $1.97.

Sawed timber trestles are likewise constructed with bents 15 or 16 feet apart. Each bent rests upon a sill which may be either a sawed 10 by 12 inch timber or a cedar log. Four 10 by 10 inch posts are used in each bent, the two outside having a batter of 2 or 3 inches per foot. Each bent has a 10 by 12 inch cap 12 feet in length. Three 6 by 16 inch stringers are placed under each rail to support the ties. The bents are braced with 2 by 8 inch or 3 by 8 inch sway and collar braces and from 3 by 8 inch to 4 by 8 inch stringer braces. These dimensions are for standard-gauge logging trestles. The caps and sills are shorter in narrow-gauge trestles and some of the braces may be lighter; therefore, from 5 to 10 per cent less timber is required. Otherwise the cost is very little less for a narrow-gauge trestle, because the work of erection is about the same.

The cost of frame trestles is usually figured at so much per 1,000 feet board measure of the lumber used. This cost is made to include lumber, bolts, and other supplies, and the labor of building the foundations and framing the trestle, the lumber being usually charged in at $12 per 1,000. The costs of several representative standard-gauge frame trestles recently constructed on logging roads are given in Table 7.



F-15944-A

FIG. 1.—MAIN LINE LOGGING RAILROAD AND DUG LANDING ON TYPICAL LOGGING OPERATION IN THE SUGAR AND YELLOW PINE REGION.

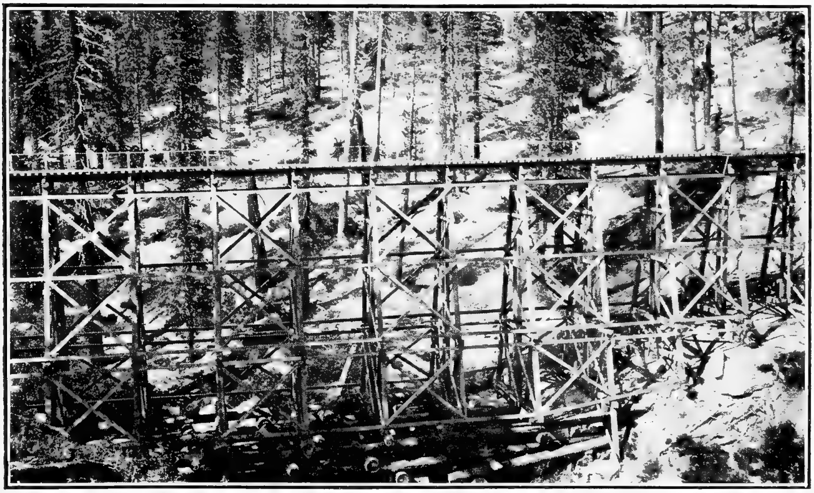


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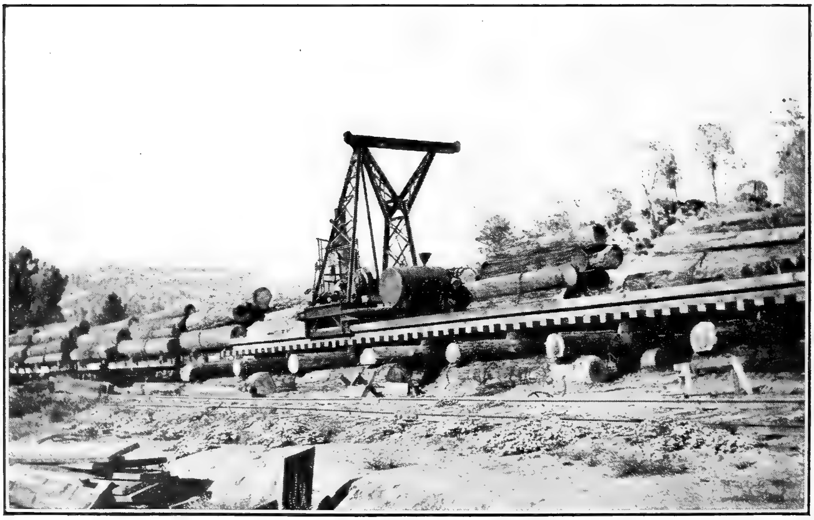
FIG. 2.—FRAME TRESTLE ON LOGGING RAILROAD IN THE SUGAR PINE REGION.

F-30927

FIG. 1.—LOADED LOGGING CARS READY FOR TRANSPORTATION TO THE MILL POND.



F-15952-A

FIG. 2.—SPECIAL UNLOADING RIG AT THE MILL POND.

Train of loaded flat cars set in ready for unloading.

TABLE 7.—*Cost of standard-gauge frame trestles.*

Length.	Maximum height.	Feet, board measure.	Total cost.	Cost per 1,000.	Cost per linear foot.
Feet.	*Feet.*				
620	52	105,000	$2,800	$26.66	$4.52
652	28	60,000	1,565	26.08	2.40
762	8	68,000	1,704	25.06	2.23
202	32	28,000	743	26.54	3.68
140	34	19,000	487	25.63	3.34
238	31	31,000	724	23.35	3.04
272	41	45,000	1,030	22.89	3.77
144	54	30,000	713	23.76	4.95

It thus appears that the cost of constructing sawed-timber trestles in this region varies from $23 to $27 per 1,000 feet board measure, depending upon the difficulties of construction, particularly the amount of work necessary in excavating foundations. A good average figure for trestle construction is $25 per 1,000. The cost per linear foot may be roughly calculated as from $2.25 to $2.75 for trestles with a maximum height of from 10 to 25 feet, from $2.75 to $3.50 for a maximum height of from 25 to 35 feet, from $3.50 to $4.50 for a maximum height of from 25 to 50 feet, and from $4.50 to $5 for a maximum height of from 50 to 55 feet.

Most of the ties used on logging railroads are sawed at the mill and hauled back to the woods. The material is usually white fir or defective cedar. Split cedar and hewed white fir are used in some instances. The usual size on standard-gauge roads is 7 by 8 inches by 8 feet. Some roads use with equal success ties 6 by 8 inches by 8 feet. The first size contains 37⅓ feet board measure, and the second 32 feet. The usual narrow-gauge tie is 6 by 8 inches by 6 feet. Sometimes, in order to cut three ties from a 16-foot timber, the length is made 5⅓ feet. The contents of a sawed narrow-gauge tie is 24 feet board measure.

The number of ties per mile varies with the size of the rail, the weight of the locomotive, and the efficiency of the roadbed. Upon permanent main-line logging roads the usual number is 16 per rail, or 2,816 per mile. Most main-line roads and spurs have 17 per rail, or 2,992 per mile. Some spurs have 18 per rail, or 3,168 per mile. The volume in feet board measure of 2,992 sawed ties per mile is 111,600 for the larger standard-gauge ties, 95,700 for the smaller standard-gauge size, and 71,800 for narrow-gauge ties. At $12 per 1,000 the cost per mile is, respectively, $1,339.20 for the first, $1,148.40 for the second, and $861.60 for the third. Where suitable young timber is available, hewed standard-gauge ties can sometimes be delivered at the track for from 20 to 25 cents each. At 20 cents each, the cost is approximately $600 per mile.

The size of rails also varies with the size of the locomotives and the maximum loads. As a rule, the use of heavy rails pays. They depreciate less in use and in lifting and relaying. They can be used with fewer ties and on a poorer roadbed than the lighter rails. The weight of the steel rails now used varies from 30 to 60 pounds per yard.

The use of 30-pound rails is rare and is limited to narrow-gauge roads with light locomotives. A few companies use 35-pound rails on standard-gauge roads with 32-ton locomotives, but such light rails are no longer popular. For narrow-gauge roads, 45-pound steel is thought to give the best satisfaction. For standard-guage roads, 50 or 56 pound steel is the choice of the most up-to-date companies. A logging superintendent who lifts his spurs several times in a season thinks that 56-pound steel is the cheapest in the end. Rails weighing 60 pounds per yard are used on main-line logging roads for heavy locomotives.

Rails are ordinarily sold by the gross ton of 2,240 pounds. The number of gross tons per mile for any size rail may be obtained by multiplying the weight per yard by 11 and dividing by 7. The weight in tons per mile of several representative sizes of rails is as follows:

Weight per yard.	Weight per mile.	
Pounds.	*Tons.*	*Pounds.*
35	55	....
40	62	1,920
45	70	1,600
50	78	1,280
56	88	....
60	94	640
65	102	320
70	110	....

The prices of steel rails fluctuate from month to month and season to season. The following 1914 prices on new rails f. o. b. San Francisco, carload lots, are, however, sufficiently exact for estimates:

25 to 45 pounds per yard, $1.55 per hundredweight, or $34.75 per gross ton.
50 to 90 pounds per yard, $1.835 per hundredweight, or $41 per gross ton.

The freight rates on rails and rail fastenings from San Francisco vary from 30 cents per hundredweight for the nearest points in the Sierras to 80 cents per hundredweight for points in northern California.

First-class inspected relaying rails are quoted f. o. b. Pacific coast terminals at the following prices:

25 to 45 pounds, $30 to $32 per ton.
56 to 60 pounds, $33 to $35 per ton.

The common rail length is 30 feet, which gives 352 joints per mile. The usual method of splicing joints is by means of angle bars rather than fishplates. The cost of standard angle bars f. o. b. San Fran-

cisco is approximately $2.05 per hundredweight. The weights of angle bars for three typical weights of rail are as follows:

Weight of rail.	Per joint.	Per mile.
Pounds.	*Pounds.*	*Pounds.*
35	12.65	4,450
45	18.75	6,600
60	32.40	11,400

Four bolts and nuts are required at each rail joint. They come in kegs of 200 pounds each, at a price f. o. b. San Francisco of about $2.65 per hundredweight. With hexagonal nuts the quantity required per mile is as follows:

Weight of rail.	Size of bolt.	Number of nuts in a keg.	Kegs per mile.
Pounds.	*Inches.*		
35	$2\frac{3}{4}$ by $\frac{5}{8}$	410	3.4
40–45	3 by $\frac{5}{8}$	395	3.6
50 and up	3 to $3\frac{1}{2}$ by $\frac{3}{4}$	245–270	5.2–5.7

The cost of standard-size railroad spikes, $5\frac{1}{2}$ by $\frac{9}{16}$ inches, f. o. b. San Francisco, is approximately $2 per hundred weight, or $4 per keg of 200 pounds. The bulk of the spikes used are of this size, though smaller sizes are used for light rails on narrow-gauge lines. The average number of kegs required per mile is about as follows:

Weight of rails.	Size of spikes.	Number of spikes per keg.	Kegs per mile.
Pounds.	*Inches.*		
45–90	$5\frac{1}{2}$ by $\frac{9}{16}$	375	28–30
40–56	5 by $\frac{9}{16}$	400	27
30–45	$4\frac{1}{2}$ by $\frac{1}{2}$	530	20

Both stub and split switches are used in this region. The better lines are now using the latter type. Two-way split switches with ground throw cost about $40 each, and the installation costs about $12. A stand costs $15 additional. A three-throw switch costs about $60.

The track laying is usually done by hand. The custom is to deliver the ties and rails at the point of construction on flat cars with a locomotive. The track-laying crew then carries the ties ahead, places them in position, and lays the rails by hand. As the work progresses, fresh supplies of ties and rails are moved ahead on a push car. The same crew which lays the track commonly does the surfacing, and the costs are commonly reckoned together.

For a standard-gauge railroad the cost is about $200 per mile for laying the track and from $350 to $500 per mile for surfacing, depending upon the difficulty and thoroughness of the work. A good average figure for laying and surfacing is $600 per mile. Because the materials are lighter and the roadbed is narrower, the cost of laying and surfacing a narrow-gauge railroad is ordinarily less. The usual cost for a narrow-gauge ranges from $450 to $550 per mile. Under favorable conditions on one narrow-gauge road a crew of 15 men and a foreman, at a daily cost of $37, lay and surface an average of 400 feet of track per day. These costs are for main lines and important spurs. For spurs used only a short time the cost of surfacing may not be over from $150 to $200 per mile, though the cost of laying track remains the same.

As the various spurs are logged out the track is lifted and transported to new spurs. Rails may be lifted once every season for from 15 to 20 years. Ties may usually be lifted about three times. The cost of lifting by hand when both rails and ties are taken up is about the same as laying track, or a little more, say from $200 to $300 per mile.

Logging railroads are commonly operated by telephone. The cost of a tree line is from $30 to $40 per mile. Ordinarily, logging roads need be at no expense for fencing.

Equipment.—The equipment, or motive power and rolling stock, consists of steam locomotives and cars or trucks. Locomotives are of two general types; rod, or straight connected, and geared. The choice between the two kinds is determined by the grades and curvature of the road.

Rod locomotives are used for the longer hauls on main-line roads. They make better time and cost less for maintenance. The cost of operation per 1,000 feet board measure is thus less than for geared engines, especially for hauls over 15 miles in length. The weight of a rod locomotive for main-line work varies with the maximum grades and the maximum load. The usual sizes are from 40 to 75 tons. The larger engines are used for long lumber or log hauls. The approximate cost prices on the Pacific coast and the tractive power of rod locomotives follows:

Total weight.	Weight on drivers.	Load at slow speed.				Cost.
		Level.	1 per cent grade.	3 per cent grade.	4 per cent grade.	
Tons.	*Tons.*	*Tons.*	*Tons.*	*Tons.*	*Tons.*	
42	31	1,240	415	140	90	$9,500
55	40	1,630	545	185	125	11,200
67	49	1,970	665	225	150	13,900
71	57	....	....	....	....	14,500

Because of the general roughness of the topography, most of the logging in sugar and yellow pine is done by geared engines. The weight of geared locomotives likewise depends upon the maximum grades and the loads to be hauled. Operators are gradually adopting heavier engines. The smallest locomotive used is a 24-ton engine, which is capable of handling 20,000 feet board measure on slight adverse grades and the empty trucks up a 6 per cent grade on a narrow-gauge road. Locomotives weighing from 32 to 42 tons are commonly used on narrow-gauge lines for switching and main-line hauls of moderate length. Such locomotives handle trains of 40,000 feet board measure. Locomotives up to 56 and 60 tons are used for long and heavy hauls on narrow-gauge lines. With adverse grades of 2 per cent such locomotives haul trains of 55,000 feet board measure. Larger locomotives weighing 65 and 70 tons are used for main-line hauls on standard-gauge roads. These locomotives pull nine empty 41-foot flats up a continuous 5 per cent grade and haul a load of 60,000 up an adverse grade of 2 per cent. Geared locomotives weighing 90 tons are used for switching by one concern, but they appear to be too heavy for the usual logging railroad track.

Three standard makes of geared engines have been used thus far in California pine logging. The 1914 catalogue prices are as follows:

TABLE 8.—*Prices of standard makes of geared locomotives.*

Weight.	Factory price with steam brake.	Freight to California.	Air brakes.	Total.
Tons.				
18	$3,600	$510	$400	$4,510
20	4,100	590	400	5,090
24	4,560	660	450	5,670
28	5,320	720	450	6,490
32	5,760	780	500	7,040
36	6,480	930	500	7,910
42	6,930	830	500	8,260
50	8,000	950	500	9,450
60	9,000	1,110	500	10,610
70	10,150	1,190	550	11,890
80	13,000	1,430	550	14,980
90	14,000	1,540	550	16,090

Weight.	Load on dry rails.				Air brakes.	Oil burners.	Total cost f. o. b. San Francisco.
	Level.	1 per cent grade.	4 per cent grade.	7 per cent grade.			
Tons.	*Tons.*	*Tons.*	*Tons.*	*Tons.*			
32	1,568	425	113	54	$350	$400	$7,290
42	2,058	558	149	72	400	500	8,790
60	2,940	798	213	102	400	500	11,115

Oil-burning equipment can be installed for from $400 to $500 per boiler. All locomotives under 42 tons in weight are loaded on flat cars; larger locomotives are shipped on their own trucks. For from 32

to 80 ton locomotives the shipping weight is from 5 to 8 tons less than the working weight.

Three types of log cars are used: Separate trucks, skeleton cars or connected trucks, and flats. Separate trucks are used on several narrow-gauge roads. They are necessary wherever long logs must be transported on crooked roads. The cost of upkeep is so large and the danger of accident so great that for pine it is usually better to buck all logs into short lengths and use skeleton or flat cars. Because of their freedom from accidents, flat cars are believed to be the best. Most firms are now using them. They may be used on any grades and on curves up to 60° on narrow-gauge tracks. Air brakes are now used on all roads except a few of the shorter narrow-gauge lines. Pin couplers are still used on most narrow-gauge roads, even for flat cars. Automatic couplers are used on most of the standard-gauge roads. Practically universal use of air brakes and automatic couplers is only a question of time.

The separate trucks used on narrow-gauge roads with hand brakes have about 30,000 pounds capacity and are 21 feet over all (two trucks); the average load is from 2,000 to 2,500 feet. The flats used on narrow-gauge roads are 24 feet in length by 7½ or 8 feet wide, and have a rated capacity of 40,000 pounds. The average loads range from 3,000 to 4,500 feet. Two types of flats are used on standard-gauge roads. The smaller is a 26-foot car with 60,000 pounds capacity; the average load is from 4,500 to 5,000. A 41-foot flat is, however, preferred, the rated capacity being 80,000 pounds; the usual load is 7,000 or 8,000 feet.

The cost of 21-foot wooden trucks equipped with air brakes and delivered on the Pacific coast is about $275 for 30,000 pounds capacity, $310 for 40,000 pounds capacity, $370 for 50,000 pounds capacity, and $470 for 50,000 pounds capacity. A San Francisco firm quotes 60,000 pounds capacity trucks rebuilt from trunk-line equipment at $425 each, and connected trucks with 80,000 pounds capacity, equipped with patent bunks, at $750 each. Both types have air brakes and automatic couplers. Another coast manufacturer quotes the prices in Table 9, f. o. b. San Francisco.

TABLE 9.—*Prices of trucks with air brakes and automatic couplers.*

Capacity.	Description.	Length.	Width.	Weight.	Price f. o. b. San Francisco.
Pounds.		*Feet.*	*Feet.*	*Pounds.*	
100,000	All steel trucks			22,000	$850
80,000	Steel bolster trucks			20,400	695
50,000	.....do			18,000	570
40,000	.....do			17,000	435
80,000	Connected truck	40	9	19,000	735
80,000	Flat (wood)	41	8½	28,500	835
80,000	Flat with bunks			28,500	900

Many firms build their own logging cars, particularly those using narrow-gauge flat cars. The complete cost of building such flats, 24 feet in length, is commonly about $600. Each car is equipped with chains for binding the logs, which cost, per car, from $10 to $20.

Upon the smaller operations usually about three sets of cars are required; one at the pond, one on the road, and the other in the woods. Larger operations require at least four sets of cars, a loaded and an empty set being in the woods all of the time. In most instances a few extra cars are in the repair shop or being used for other purposes. With a hauling distance of 10 miles or more, at least two locomotives are required; one for the main-line haul and the other for switching the loads out to the main line.

Upon a road 16 miles in length, including spurs, one 35-ton main-line rod engine, one 42-ton geared engine, and 80 flats 24 feet in length are required for a daily output of 160,000. The usual train load is 16 flats. A company operating 11 miles of railroad with heavy grades has one 32-ton and two 42-ton geared locomotives and seventy 24-foot flats. The usual train is 14 cars and the daily output is about 250,000. A firm with a daily output of 220,000 has 20 miles of logging railroad with heavy grades and 10 miles of spurs. Two geared locomotives, one 56 and the other 60 tons, are operated on the main line. Two 37-ton geared locomotives are required for switching on the spurs. The usual train load is 18 cars, and a total of one hundred and fifty 24-foot flats are required.

Operation.—A general idea of the operation of logging railroads has already been given in the discussion of equipment. The crew required, as well as the amount of equipment, depends upon the daily output and the resistance. Upon small operations one locomotive and crew is sufficient. This engine hauls the empties out to the woods, switches them to the yarders, picks up the loaded cars, and takes the train to the mill. In most instances two trips are made daily. Larger operations with longer railroads keep one locomotive in the woods distributing empties and switching out the loaded cars to a point where they are picked up by the main line locomotive. Still larger operations have two main-line locomotives and two or more locomotives switching in the woods.

Geared locomotives are slower than rod engines and more of them are necessary for the same mileage. Enough crews and locomotives should be maintained on any operation to keep the loaders supplied with empty cars. Delays caused by lack of cars materially increase the cost of yarding and loading.

One train crew is assigned to each locomotive. On most logging railroads the customary crew consists of a conductor, brakeman, engineer, and fireman. The daily labor cost is from $15 to $16 for 10 hours work. Overtime at the regular rates is allowed for any

work in excess of this period. On long runs or heavy grades this crew may be increased by a second brakeman, thus adding from $3 to $3.50 to the daily cost. Where there are several crews the services of a dispatcher are required.

On account of the danger of setting fires with sparks from wood, the common fuel for locomotives is oil. Burning oil also renders a locomotive somewhat more efficient than when wood is used. Oil is also easier to handle and saves considerable time. The amount consumed daily depends upon the size of the locomotives and the resistance of the road. For example, a 35-ton rod engine on a 12-mile main-line haul, with grades of 1 per cent loaded and 2½ per cent empty, consumes 10 barrels daily. A 70-ton engine on a 10-mile main-line haul, with grades of 2 per cent loaded and 5 per cent empty, consumes 20 barrels daily. The present cost of fuel oil delivered at the various logging railroads in California ranges from $1.10 to $1.30 per barrel. A good figure for estimating fuel costs is $1.20 per barrel.

Where fuel oil is not obtainable at a reasonable cost, which is usually at mills with lumber flumes, wood must be used—either slab wood or split white fir. The cost is from $1.75 to $2.25 per cord, besides the time spent in loading it on the tender. A 42-ton geared locomotive working fairly hard requires about 7 cords per day. Thus it appears, eliminating the extra efficiency of oil and loss of time on the part of the train crew, that the daily cost is much the same. One operator whose wood costs $2.50 per cord calculates that he saves $1.50 daily on a 35-ton locomotive, and states that the oil-burning locomotive handles 16 cars and a wood burner but 14.

The expense chargeable to railroad transportation of logs, in addition to train labor and fuel, includes the cost of lubricating oil and waste, upkeep of locomotives and cars, and upkeep of the roadbed. Sometimes unloading is also included. The minimum expense, even for the shortest hauls, is from 35 to 50 cents per 1,000. The cost on a 5-mile haul where one locomotive and crew is employed to get out 60,000 daily is approximately 60 cents per 1,000, divided into 32 cents for labor and fuel, 12 cents for maintenance of way, 11 cents for repairs to rolling stock, and 5 cents for oil, waste, and supplies.

The cost for one haul of from 14 to 16 miles with favorable grades and good roadbed is 84 cents per 1,000, approximately as follows: Train labor, 20 cents; fuel, 14 cents; maintenance of way, 23 cents; supplies, 3 cents; inspection and maintenance of equipment, 24 cents per 1,000. Two oil-burning locomotives are required for a daily output of 160,000. Upon a difficult 12-mile main-line haul two geared locomotives move 280,000 daily at a cost of 94 cents per 1,000 as follows: Labor and dispatching, 22 cents; fuel, 18 cents; oil, waste,

etc., 2 cents; labor for maintenance of way, 18 cents; supplies for maintenance of way, 8 cents; repairs to locomotives, 17 cents; and repairs to cars, 9 cents per 1,000.

In general, under normal conditions the total cost of railroading, including maintenance, is approximately as follows: From 50 to 60 cents per 1,000 for from 4 to 5 miles, from 70 to 80 cents per 1,000 for from 7 to 10 miles, from 80 cents to $1 per 1,000 for from 10 to 16 miles, from $1 to $1.20 per 1,000 for from 18 to 22 miles, and from $1.30 to $1.50 per 1,000 for from 25 to 35 miles.

Very few rates for hauling pine logs in California have been established on common-carrier railroads. Three such representative rates are: 30 miles, $1.55 per 1,000; 45 miles, $2 per 1,000; and 50 miles, $1.50 per 1,000. The first two are rather high and the last is very reasonable. Equipment is furnished by the carriers in all three instances.

Maintenance.—The maintenance of a logging railroad is divided into maintenance of rolling stock and maintenance of way. The upkeep of equipment begins with car inspection. While each trainload of logs is being unloaded at the mill the cars are inspected. Small repairs are made immediately, and cars in bad order are switched to the car shop. For a double-band mill the usual inspection crew consists of two men who work between times in the car shop. Where the number of cars is larger than common, or repairs are extra heavy, a third man is required in the car shop. The upkeep of trucks appears to be more than the cost of repairing flats.

Repairs to locomotives and ironwork are made in the blacksmith and machine shops maintained at the mill. For a double-band operation, the common crew in the blacksmith shop is two men, and the machine shop crew is three or four men. In addition to repairs on railway equipment, the machine shop handles both sawmill and heavy donkey repairs. The locomotives are usually brought into the shop in winter and more or less thoroughly overhauled. The cost of maintaining railway equipment depends upon the efficiency of the equipment and the length and severity of the haul. Under ordinary conditions it may be said to average from 15 to 25 cents per 1,000.

The principal part of maintenance of way is the labor of section crews. The customary crew consists of a foreman and four workmen at a daily cost of $13.50. Usually such a crew can keep from 7 to 10 miles of track in satisfactory order. Two crews are required to keep up a 14-mile line; with a daily output of 160,000 the cost is 17 cents per 1,000 and with an output of 220,000 it is 12 cents per 1,000. With the exception of a small expenditure for tools and rail fastenings, the rest of the cost of track maintenance is for tie replacement. Fir ties used on spurs last three or four years and can be

lifted and relaid three times. Where they are left in place the customary sawed fir ties must be entirely replaced in five or six years. Cedar ties last considerably longer.

INCLINES AND LOG HOISTS.

Inclined tracks for lowering or hoisting logs are becoming an important engineering feature in connection with logging railroads. At points where the country rises rapidly and it is necessary for the continuation of the logging railroad to be at a considerably higher level, an incline will satisfactorily reach the upper level and obviate the construction of switchbacks or detours. Timber may often be opened up by an incline where the cost of a continuous logging railroad would be prohibitive. Furthermore, it usually costs less to operate an incline than several miles of heavy-grade railroad. Frequently inclines can be used advantageously for hoisting logs out of coves or pockets below the level of the main track.

Existing inclines have proved that their use may be extended and that no engineering conditions are likely to be met with in construction which will prove insurmountable. A common type is one in use in the central Sierras for lowering logs to the main line from a short narrow-gauge line higher up the mountain. The total length is 4,770 feet and the total descent is 840 feet. Thus the average grade is 18 per cent, with a maximum of 35 per cent and a minimum of 14 per cent. The line is a tangent for 3,600 feet, but there are two short 5° curves near the bottom. The track is 36-inch gauge with 40-pound rails, and narrow-gauge ties spaced about 10 or 12 per rail. It is well ballasted with dirt, and apparently no other provision is made to prevent the track creeping downhill. Both the initial cost of construction and the maintenance of way are less than for an equal length of railroad, because no provision need be made for the pounding action of a locomotive. The lowering equipment consists of a 10 by 12 inch hoisting engine connected with a steel drum about the same size of that on a large roading engine. A wheel about 6 feet in diameter is attached to the drum for braking. The cable used is ordinary 1-inch wire logging rope. Two skeleton log cars are lowered at one time, each with a load of 3,000 feet board measure. The average time of a trip is from 20 to 30 minutes. The loaded cars come down by gravity, controlled by the brake, and when unloaded are hauled up by the engine.

The largest incline in use in this region is one about 8,000 feet in length, which has a fall of 3,100 feet, or approximately 45 per cent. The grade is very uneven, however, varying between a maximum of 78 per cent and a minimum of 10 per cent. The track is standard gauge and is well ballasted. The upper half is double track and the lower half single track. Including gravity switching

tracks at top and bottom and a 14 by 14 inch lowering engine, the total cost was approximately $100,000. There are three trestles and one bridge with a center span of 76 feet. Except for the passing switch the track is perfectly straight.

The method of operation is to lower a loaded car and hoist an empty one simultaneously. A 1½-inch cable is used, which is supported by steel sheaves. Because of the configuration of the slope, at three points these sheaves are suspended above the track to hold the cable down. The cars used are 80,000 pounds capacity 40-foot flats, with a bulkhead on the front end. The average load per car is about 6,000 feet, weighing approximately 24 tons. One car can be lowered every 10 minutes, though the customary working speed is about four or five cars per hour.

The loads and empty cars are handled at each end by gravity switches without locomotive switching except for setting in and taking out the loaded and empty trains. Oil is used as fuel in the hoisting engine. The cable is used for one season and then taken to the woods and used as a yarding line.

Log hoists may be spurs built down into coves at a grade of from 10 to 20 per cent where otherwise a chute would be required. An extra logging donkey is ordinarily employed to let an empty car down and haul it up again after it is loaded. Another type of log hoist is one where the loaded cars are hauled up from one section of the logging road to another. One such hoist located in the southern Sierras is 2,200 feet long, with an average grade of 30 per cent and a maximum grade of 40 per cent. The track is narrow gauge with 35-pound rails and is constructed and ballasted much the same as an ordinary logging railroad. It is straight except for one 9° curve. The engineer in charge states that if there is more than one curve, they must be in the same direction. A hoisting engine is employed to haul the logs up this incline on skeleton frame cars, one or two cars at a time. The cable used is a 1⅛-inch wire rope.

UNLOADING.

Unloading from horse trucks is usually done by hand with peavies, otherwise the general method of unloading logs at the mill pond is the following throughout the region. An unloading track is constructed along the mill pond with the outer rail raised to give the cars a slant toward the pond. Ordinarily a sloping deck is constructed from this track out over the edge of the pond. After the binding chains are loosened, a cable terminating in a hook is used to roll the logs from the car to the log deck. Since the pull must be toward the pond and there can be no obstruction between the car and the pond, the methods of operating and supporting this cable are varied. One method is to have a stationary boom built over the track from

the land side. The cable passes through a block on the end of this boom and is operated by a small steam winch furnished with steam from the sawmill boilers. As each car is unloaded the train is shifted ahead by the locomotive or by gravity.

Another system is to place the steam winch with its own boiler upon a cribwork in the pond. The block may be attached to an overhead cable parallel to the track or the cable may be used without any supporting block. The third system is to have a special unloading machine which shifts itself along a second track on the land side of the unloading spur. No shifting of the train being unloaded is necessary. This unloader consists of a boiler and winch mounted upon a car. It may have a steel boom extending out over the loaded cars, or a block may be slung to the log deck in front of each car unloaded.

In some instances the train crew does the unloading. The fireman operates the winch, the conductor and brakeman unbind the loads and handle the unloading hook, and the engineer shifts the train. In such cases it is difficult to separate the cost of unloading from the cost of railroading. Upon one operation where the unloading is done in this manner, one pond man handles the unloading hook. A train of 55,000 is switched in and unloaded in about 40 minutes, the actual unloading requiring 30 minutes. With ample allowance for maintenance of winch and cable the cost of this unloading is $0.025 per 1,000. Another way is to have the unloading crew engage in pond work, such as sorting logs and raising sinkers, when not required for unloading. In such cases the cost of pond work and unloading is usually kept together. Upon certain large operations where self-moving unloading machines are used the practice is to have a separate unloading crew. In one case this crew consists of 1 winchman, 2 unloaders, and 1 man shoveling bark off the deck. This crew unloads 280,000 daily at a labor cost of $11, or about 4 cents per 1,000. The usual cost of unloading is from 2 to 4 cents per 1,000.

WOODS SUPERVISION.

The field supervision of logging is a very important item and may make the success or failure of a lumbering operation. Sawmilling can be pretty well standardized, but the logging of each tract must be planned on the ground, and in this planning is the chance either to cut or swell costs. Not only is the work planned for each particular area but the operations for the whole tract must be laid out long in advance. This calls for competent woods superintendents and logging engineers who are qualified to plan the layout of the railroad and logging, as well as to supervise the work.

In addition to the logging superintendent, woods supervision includes the camp foreman, timekeepers, night watchman, and chore

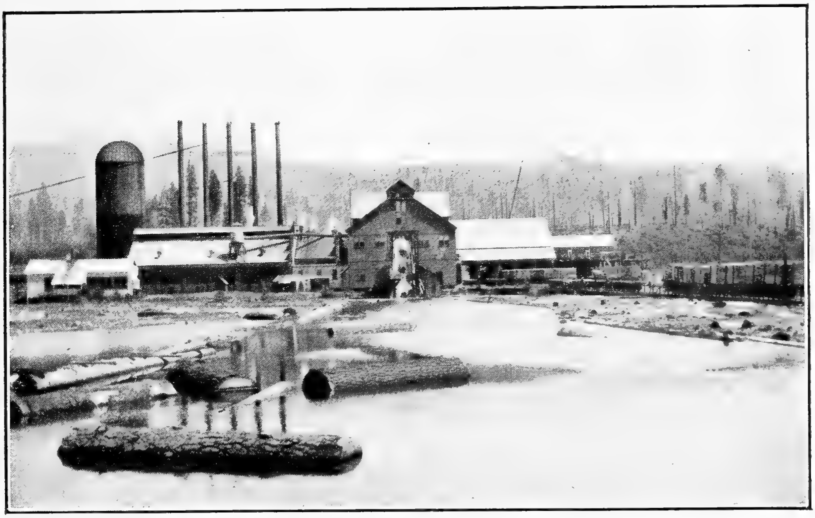


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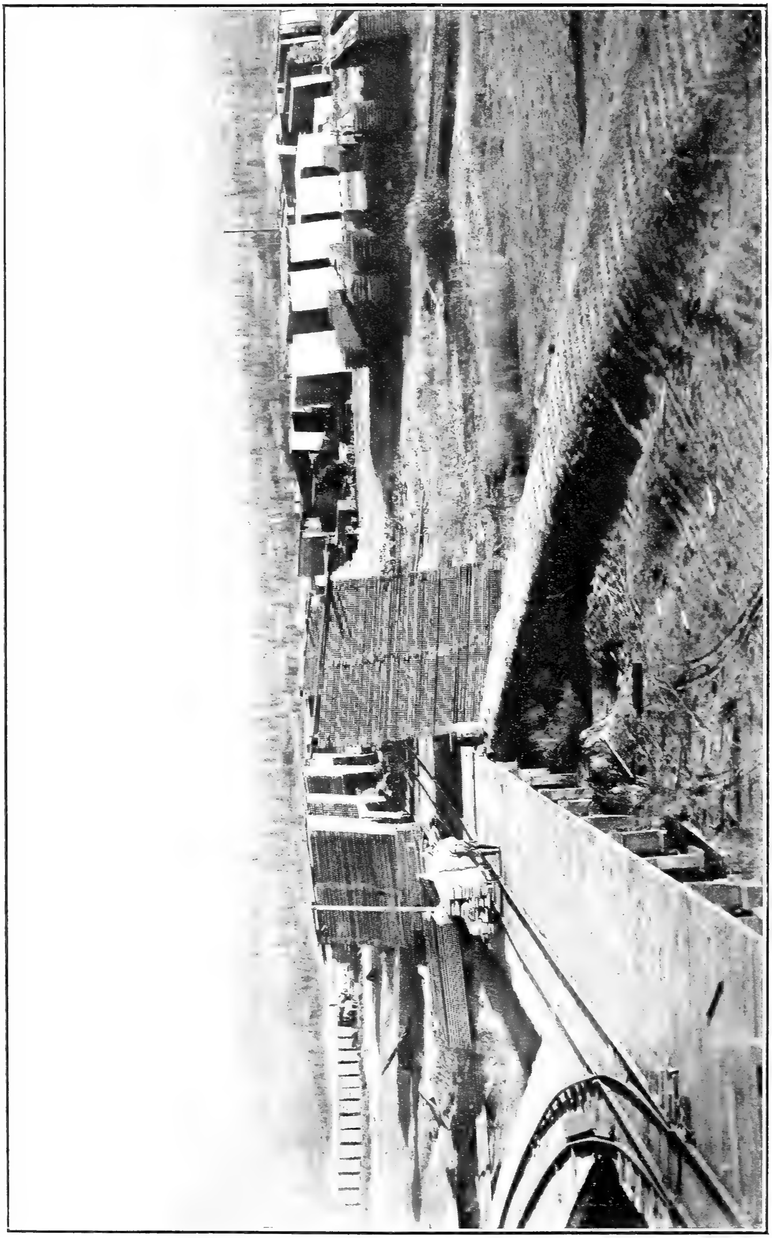
FIG. 1.—LOG POND AND LARGE DOUBLE-BAND SAWMILL AT A REPRESENTATIVE CALIFORNIA PINE LUMBERING OPERATION.

F-95316

FIG. 2.—TYPICAL SMALL CALIFORNIA SINGLE-BAND MILL. LOGS SUPPLIED BY TRUCK LOGGING.



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LUMBER YARD AT A SMALL SINGLE-BAND MILL SAWING CALIFORNIA PINE.

boys. One operation, with work divided into two camps and a daily output of 240,000, has the following force: One superintendent at $3,500 per annum, two camp bosses at $200 per month, 2 timekeepers at $70 per month, 2 watchmen at $40 per month. The daily cost, including board, is $46.50, which is equivalent to 19 cents per 1,000. A representative operation of 150,000 daily, with its work divided into two camps, has the following force: One superintendent at $3,000 per year, 1 camp boss at $150 per month, 1 camp boss at $125 per month, 1 timekeeper at $70 per month, and 2 watchmen at $40 per month. The daily cost, including board, is $34.60, which is equivalent to 23 cents per 1,000.

Another operation, with its work divided into three camps and a daily output of 500,000, has the following force: One superintendent at $4,000 per annum, 1 camp boss at $1,900 per annum, 2 camp bosses at $1,445 per annum, 3 timekeepers at $70 per month, 3 scalers at $75 per month, 4 watchmen at $40 per month, and 3 chore boys at $40 per month. The daily cost, including board, is $114.70, which is equivalent to 23 cents per 1,000. Calculated in the same manner, the cost for one representative operation, turning out 225,000 daily, is 23 cents and for another operation, turning out 160,000 daily, is 21 cents per 1,000. These figures should be increased by from 3 to 4 cents per 1,000 for work done by the railroad engineer not chargeable to construction, and other like expenses. Thus, the cost of woods supervision for large logging operations in California pine timber ranges from 22 to 27 cents per 1,000. On small horse-logging jobs the cost is generally the salary of a woods foreman or part of the time of the operator.

PART III. MANUFACTURE.

MILL POND.

Practically all sawmills in this region with a daily capacity of over 20,000 have log ponds. A few circular mills of 35,000 capacity or less do not have ponds, because of the impossibility of getting sufficient water at a reasonable cost. Mill ponds are almost indispensable for larger operations. They provide a cheap method of storing logs ahead against possible interruptions of logging operations or for extension of the milling season in the fall. In addition, they furnish the most economical means of delivering a continuous supply of logs from the railroad to the mill deck. Logs can be sorted as desired and a continuous run may be made of any species or grade. Immersion of logs in ponds tends to wash off dirt and gravel accumulated during logging and to leach out pitch and sap.

Ponds may be secured at mill sites by utilizing natural lakes or by damming small creeks or ravines. Where the mill site is on a

flat, the pond is usually constructed by excavating the center and building earth dykes on the low sides. In some instances a ditch must be constructed for supplying water.

For circular mills cutting from 30,000 to 40,000 daily, the usual size of the pond is from one-half to one acre. For single-band mills where storage is not an item, the ponds vary from 1 to 4 acres. The size of ponds at double-band mills depends upon the possibilities of each site and the desire of the operator to store logs for a run of a month or more in the fall. Such ponds range from 4 to 14 acres. The usual capacity of a pond, excluding sinkers, is from two-thirds to three-fourths of a million feet of logs per surface acre. Where necessary, logs may be piled in a pond with an overhead trolley, thus about trebling the capacity. The cost is, however, very large.

The work upon a log pond may begin with unloading the cars, and includes sorting, raising sinkers, and delivering logs to the haul-up. In the yellow pine of the eastern Sierras sinkers are practically unknown, and the unloading is customarily done by the train crew. The pond crew, therefore, consists of one man for a single-band mill and two men for a double-band mill. One man is stationed at the lower end of the log slip to pole the logs into position for the hoisting chain. The other man poles the logs to within reach of the first and does sorting and general pond work. For a daily output of 120,000 the cost is about 5 cents per 1,000, which may be considered the low figure for such work in good-sized plants.

Since both sugar-pine and white-fir butt logs sink on being placed in the water, provision must be made for raising sinkers from ponds where these two species are logged. The simplest scheme is one used at a double-band mill with a small pond. The log cars are unloaded by a stationary overhead boom at a point very near the log slip. A swinging boom with a steam winch and cable is located on a cribwork in the pond. After each train is unloaded, the sinkers are picked up by tongs and swung around by the boom to within reach of the pikeman at the log slip. The crew consists of two pondmen delivering logs to the slip, one man in a flatboat attaching tongs to sinkers, and one winchman. One-third of the time of the winchman is devoted to unloading. The night crew contains only the two pondmen. The total daily cost is therefore $17, which, distributed over 250,000 feet, is 7 cents per 1,000.

At another operation, with a large number of sinkers, the cost of pond work is still greater. The pond crew does the unloading, using a winch located on a cribwork in the pond. The entire crew, except one man, works at unloading, and the average time required for an 18-car train is 20 minutes. The unloading is done at a point some distance from the log slip. When not unloading, the crew is at work raising sinkers, sorting logs, and shifting logs to the mill end

of the pond. The crew consists of eight men, one of whom poles logs to the jack-works. The monthly labor cost is about $630, or 11 cents per 1,000, of which about 3 cents is chargeable to unloading. At one other large pond, where the logs are unloaded on the opposite side of the pond from the mill, the cost of picking up sinkers and storing logs is calculated for a season's run at 5 cents per 1,000, and delivering to the log slip at 4 cents per 1,000.

SAWMILLS.

Strictly speaking, the work in a sawmill is confined to sawing, which includes all activities from the removal of the logs from the pond to the delivery of rough lumber for sorting at the rear of the mill. Sorting lumber is in the transition zone between sawmill and yard. For convenience it will be considered as part of the milling operation, together with the sawing.

So far, the practice in this region is to construct the sawmill as close as possible to the timber. Small mills are almost invariably located in the lower part of the logging unit. When the unit is cut out the mill can then be moved to a new site. For large mills the site must be accessible to enough timber for a run of sufficient length to warrant the mill investment, say, from 15 to 25 years. In addition to accessibility from the logging operations, there are several other factors which affect the practicability of any site. There must be space for a log pond and a sufficient water supply. There must also be room for the sawmill, the sawmill camp, and the lumber yard. Further, the climate should be suited to air drying of lumber, and there should be transportation facilities for the lumber.

Lack of cheap water or railroad transportation for logs has made it advisable to place large mills on the nearest permanent site to the logging operations.

Most mills in the Sierras are a long distance from trunk-line railroads, and a lumber railroad or flume is necessary. The drying yards and finishing plants are commonly located at the lower terminals of these railroads or flumes, because drying and handling conditions are better there. The location of a sawmill in the valley or in a fair-sized town gives an advantage in the disposal of by-products which would not otherwise be utilized. However, under present conditions this advantage is not considered by operators as of sufficient weight to offset the necessity of transporting logs for considerable distances. As mill utilization improves in the future, this condition may change and the location of mills nearer centers of population be found profitable in many instances.

The present close connection between sawmills and logging operations results in joint ownership and management of the two throughout the region. Thus, the size of a mill is closely related to the extent

of the logging operations, and both are governed by the investment in transportation facilities. The sawmills in operation vary in size from small portable rotary mills to large double-band mills with gang saws. In the description which follows, the various types of commercial sawmills are taken up in order, the smallest first. The improvements, equipment, sawing, and approximate cost of sawmilling are outlined for each. The descriptions of equipment and operation are given in greatest detail for large mills. All figures regarding outputs and costs are based on mill tally instead of log scale.

SMALL CIRCULAR MILLS.

Practically all the small mills supplying local trade, including the few water-power mills, are circular mills. There are no sash saws used so far as is known. Some of these small mills have an output as low as 10,000 feet board measure daily. The standard output for mills operating for a steady local demand or entering outside markets in a small way is from 20,000 to 25,000 daily.

These mills may either have a log landing or a small pond. Usually a chute and cable are employed for hauling the logs into the mill. Inside the mill the logs are turned on the deck and carriage by an overhead cable turner. The carriage is hand set and has either a rack and pinion or a cable drive. The saws are inserted tooth circular, there being a lower and an overhead saw on account of the large size of the logs. A series of dead rolls extends from the saw frame to the rear of the mill. Generally a small circular gang edger, with three saws, is located to the rear of the main saw. Two cut-off saws for trimming are located along the series of rolls. Some mills may have a light two-saw adjustable trimmer.

The power plant commonly consists of one engine of from 65 to 75 horsepower and a single boiler of about the same capacity. The mill is ordinarily inclosed in a frame building with a board roof. The building need have but one story. The engine and boiler are usually placed together in a lean-to adjoining the main building. The cost of such a plant complete, without yard and pond, is ordinarily about $9,000 or $10,000. In most cases, though, the latter figure will include the yard, pond, and other improvements.

The mill crew consists of the following men: One man on log hoist, 1 dogger, 1 setter, 1 sawyer, 1 offbearer, 1 edgerman, 2 cut-off men, 1 slabman, 1 sawdust man, 1 engineer, 1 foreman, and 1 night watch.

The daily labor cost for this crew is approximately $42.50. Prorating this amount over a daily average of 24,000 gives a labor sawing cost of $1.77 per 1,000. Since a considerable part of the upkeep of the mill is included in the above daily wages, there is no very definite information available relating to maintenance and supply charges.

These charges are judged, however, to be from 25 to 40 cents per 1,000 in addition to the above labor cost. The cost of sawing is thus from $2 to $2.15 per 1,000.

At mills of this size the grading and sorting is not so intensive as at large mills. The lumber is commonly partially sorted as it is loaded upon yard cars by two men, one of whom does the grading. The daily wages for this crew are about $6.50, or 27 cents per 1,000. Thus the cost of sawing and loading on cars ready for yard delivery is commonly from $2.25 to $2.50 per 1,000. Some mills efficiently managed do it for $2 per 1,000; others require $2 per 1,000 for sawing without maintenance.

LARGE CIRCULAR MILLS.

The large circular mills are commonly single mills owned by small operators. They are well adapted to logging chances not large enough for the investment involved in a band mill. For larger chances they generally can not compete with band mills on account of greater sawing cost and greater waste in sawing. Practically all the double mills started with circular saws have been changed into band mills.

Large circular mills are usually built to cut from 30,000 to 45,000 feet of lumber in a 10-hour day. When they are working well during the middle of the summer season the average output is generally about 40,000 or 41,000 per day. However, the output at both ends of the season is not quite so large, and a fair seasonal average is about 38,000 daily. The increase in output over that of the small circular mills is due to greater power and heavier and more efficient equipment.

A representative mill of this capacity is usually equipped with a chute or a log car operated by a cable and a single-geared log jacker for hoisting logs into the mill. The log deck has a log stop and loader, a steam nigger, and an overhead turner. The carriage may have either two or three head blocks and be either steam or cable feed. The set works are usually operated by hand. The saws are circular and two in number, one being placed directly over the other. The diameter of the lower saw when new is usually 58 inches. Some plants have inserted-tooth saws, but most operators prefer solid-tooth saws because of the smaller kerf. A filer must be added to the crew when solid-tooth saws are used.

Beginning at the saw frame, a series of dead rolls extends to the rear of the mill. Beside these rolls is located a gang edger, ordinarily about 52 inches wide, with four saws. The trimmer is located at one side still farther toward the rear of the mill. It may be of the gang type with seven saws or of the adjustable type with two or three saws sliding on a shaft. Some mills of this type which have a market for slab wood are also equipped with a three-saw slasher.

The power plant usually consists of an engine and two boilers. The engine is frequently underneath the mill and the boilers in a separate boiler house. The mill floor is commonly raised from the ground in order to make room underneath for shafts, belting, and conveyors. The building is frame with a board roof. A conveyor is installed for carrying out sawdust and a light track built to an outside burner for slabs. The cost of the equipment in such a plant is about $10,000. The cost of delivery, installation, and construction of the building brings the cost of the completed plant up to $15,000 or $17,000, exclusive of pond and yard.

In a representative mill of this type two men are required to operate the log jacker, do the scaling, and roll the logs down on the deck. The logs are turned on the carriage by the steam nigger; and two men, a setter and a dogger, handle the setworks and the dogs on the carriage. The sawyer is located at the saw and the offbearer places the boards and slabs on the rolls as they are sawed from the log. The pointer transfers boards from the rolls to the edger table and the edgerman manipulates the edger. One man is stationed at the rear of the edger and two men manage the trimmer. The slabs are loaded on cars and delivered to the fuel piles or slab fire by two men. The remainder of the crew consists of a foreman, an engineer, a fireman, a filer, a millwright, and a night watchman. The total crew contains 19 men, and the daily cost is about $63.20. Based upon an average daily output of 38,000, the direct cost of sawing is $1.66 per 1,000. With a daily average of 40,000 the direct cost is $1.58 per 1,000. The labor cost of maintenance is largely covered by the wages of the sawyer, engineer, and millwright. The additional cost for supplies and overhauling is judged to be from 25 to 40 cents per 1,000. Thus the cost of sawing is from $1.90 to $2.10 per 1,000 feet.

There are two common methods of loading lumber for yard delivery at these mills. One is to load the boards on small cars directly behind the trimmer; the other is to allow the lumber to pass upon a sorting table behind the trimmer, from which table it is loaded on various lumber cars or trucks. The latter method allows a better separation of the different grades. The crew is the same in each instance, a grader and two sorters. The daily labor cost is $9.25, or the equivalent of 24 cents per 1,000 for a daily output of 38,000. Thus the average cost of sawing and sorting in mills of this class is from $2.10 to $2.40 per 1,000, depending upon the cost of labor and material and the class of lumber manufactured.

Circular mills are frequently intermittent in operation and thus incur costs while idle. Crews are often less efficient than in larger mills, and the mill equipment and yard facilities generally are not such as to obtain the best quality of lumber from the logs.

SINGLE-BAND MILLS.

The principal advantages of a band mill are the small saw kerf and high speed in sawing. The investment is larger than for a circular mill and the daily output must be greater. This calls for heavier and better equipment all through the mill.

Single-band mills are well adapted to medium-sized logging chances and have many advantages over both smaller and larger mills. The initial investment is not too great for an operator of moderate means; and the operation lends itself peculiarly well to management by one man. Thus, in many instances it is the most desirable mill for operating in National Forest timber. Because of certain disadvantages in operation and upkeep, the sawing cost is frequently a little higher than for a double-band mill. Where the output of a single-band mill in 10 hours will not warrant the required investment in logging facilities and stumpage, it is often better to work a day and a night shift than to construct a double-band mill. The disadvantage of working double shift is that little time is left for mill inspection and repairs.

Although similar in type, single-band mills throughout the region vary in details and thoroughness of construction, according to the length of time they are to be used and whether they are to be operated for one or two shifts daily. The initial cost varies from $35,000 to $75,000, exclusive of pond and yard. The 10-hour output likewise ranges from 50,000 to 65,000. The output for a mill operating double shift is from 110,000 to 120,000 per day.

The equipment varies in the same way as the construction; that is, heavier equipment is used in the mills intended for operating double shifts or producing the maximum daily output. The sawing equipment of a representative mill consists of the following articles:

1 log jacker.
1 log kicker.
1 log stop and loader.
1 steam log turner.
1 8-foot or 9-foot band mill, either right or left.
1 carriage, with either two or three head-blocks.
Steam or power set works for carriage.
Steam or cable feed works for carriage.
1 series live rolls.
1 60-inch gang edger.
1 lumber transfer to trimmer.
1 slash transfer.
1 overhead slasher.
1 gang trimmer.
1 lumber-sorting transfer.
1 chain refuse conveyor.
Filing room, equipped for filing band and circular saws.

The mill building is commonly of two-story frame construction, 35 or 40 feet in width by 120 feet in length. The roof is often made of corrugated iron instead of shingles or boards. The boilers are placed in an adjoining boiler house, which may be of wood, corrugated iron, or brick, depending upon the permanence of the mill. The engine room is usually underneath the mill floor. A satisfactory power plant consists of a 16 by 36 inch engine and two 60-inch by 16-foot boilers, the aggregate development being from 250 to 300 horsepower.

The crew of a representative single-band mill is made up of the following men: One man scaling and operating log jacker, 1 man on log deck, 1 sawyer, 1 setter, 1 dogger, 1 offbearer, 1 pointer, 1 edgerman, 2 men at rear edger table, 1 man tending cut-off and slasher, 2 men at trimmer, 1 slab and burner man, 1 foreman, 1 filer, 1 millwright and oiler, 1 engineer, 1 fireman, 1 laborer clearing up bark and refuse, and 1 watchman.

The daily cost of this crew is approximately $75. With a daily output of 60,000 the direct cost of sawing is $1.25 per 1,000. The average cost of maintenance, including supplies and repairs, is approximately 50 cents per 1,000. This is an average for the normal life of a mill, the repairs being less during the first few years. Thus the average sawing cost is about $1.75 per 1,000, varying normally from $1.65 to $1.85 per 1,000. Some single-band mills by efficient arrangement and more elaborate equipment cut down the above crew without reducing the output, until the cost of sawing is as low as for a double-band mill.

All single-band mills use a table with chain conveyor for grading and sorting the lumber after it leaves the trimmer. The standard crew consists of one grader and four sorters, and the daily pay roll is about $13.75. The cost for a daily production of 60,000 is therefore about 23 cents per 1,000. Thus the total cost of sawing and sorting normally ranges from $1.90 to $2.10 per 1,000.

DOUBLE-BAND MILLS.

Double-band mills produce the bulk of the lumber output of the region, and the description of their equipment and sawing operations is given below in detail. The typical mill with twin band saws is frequently increased by the addition of a resaw or a gang saw. In some mills one of the band saws is of the so-called pony type, and one scheme of mill layout involves a single band and a gang. The standard type is accordingly described first, after which the various modifications are mentioned. A rough plan of the layout of a double-band mill is given on page 73. No two mills are designed exactly alike, and the plan given is not advanced as a model but is simply intended to show the general type of sugar and yellow pine mills and to assist in a clearer understanding of the text.

The first step in the operation is the removal of the logs from the pond. Since the sawing floor is commonly elevated, it is generally necessary to hoist the logs some distance. This is accomplished in two ways; by the use of a steel car drawn up on a track by a cable, or by hauling the logs one at a time up a log slip by an endless sprocket chain. The latter method is the better, especially when the logs are to be hoisted a considerable distance. Less power is required for the other method, however.

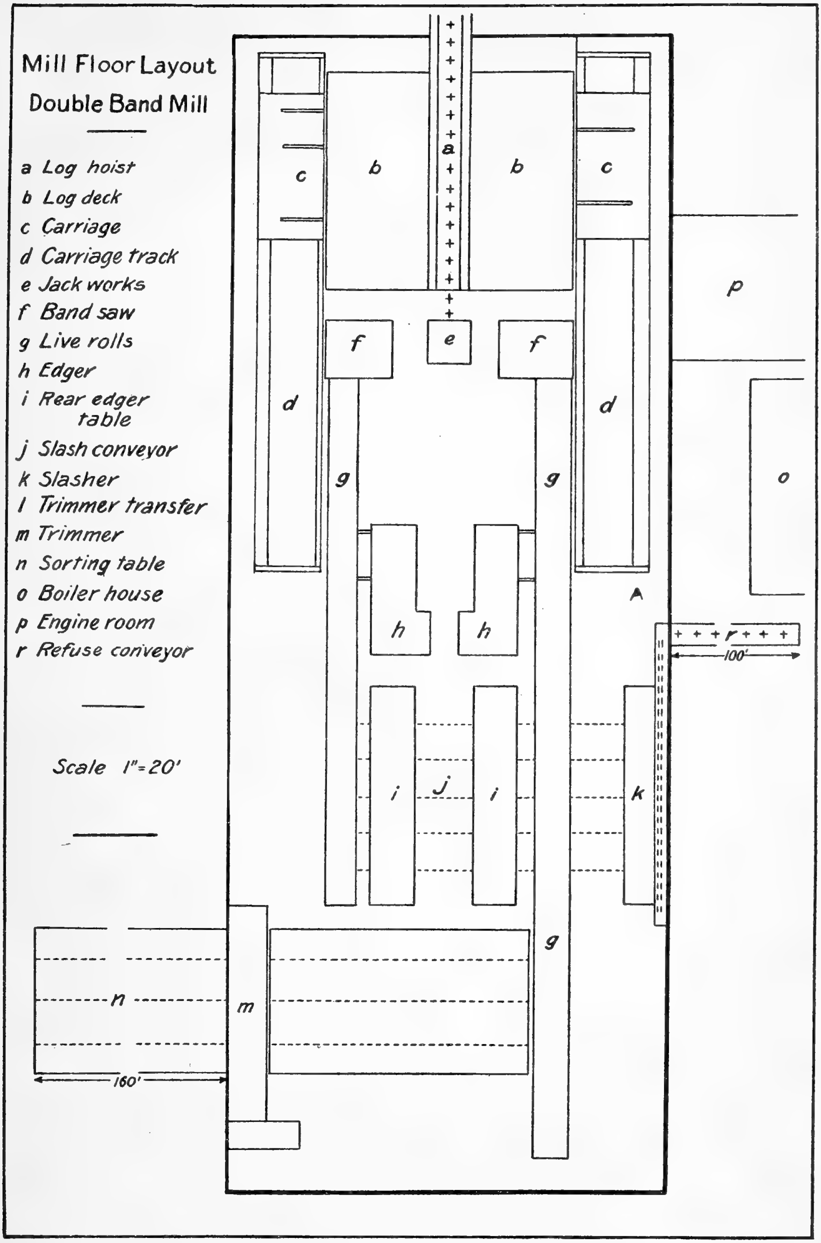

FIG. 2.—Mill floor layout.

The log hoist enters about the center of the front end of the mill building. A log deck slopes either way from it toward the sides of the mill; one for the left-hand and the other for the right-hand saw. Each log deck is about 30 feet long and 12 or 14 feet wide. One man is stationed at the head of the log hoist to operate the jack works and scale the logs. Where a log slip is used he also operates the steam log kicker, an appliance that shoves the logs out of the slip onto one or the other of the decks.

One side of the mill, that with the smaller saw, is commonly selected for sawing the smaller logs. Thus the small logs are kicked out on the deck on that side, which for the sake of convenience may be considered in this description as the right-hand. Usually two men are kept on the log decks to clean the logs and remove all dirt, gravel, etc., from the bark. As the logs roll down the decks they are stopped and held until ready for loading on the carriage by the steam log stop and loader. The actual loading and turning of logs on the carriage is done by a steam log turner on the left-hand deck and a steam nigger on the right-hand, the latter having the more rapid action and therefore being better adapted to handling small logs.

The left-hand carriage is equipped for handling large logs and has two headblocks about 10 feet apart. It is usually propelled by steam (shotgun) feed. The other carriage is usually lighter and equipped with a faster feed, which may be either steam or a cable operated by a twin engine. The right-hand carriage often has three headblocks, spaced 10 and 5 feet apart. Both carriages usually have the same kind of set works, which may be either rope drive or steam, the former preferred. Three men are required on each carriage, the setter to operate the set works and two doggers to set the dogs at each end of the log.

The sawyer is stationed directly between the log deck and the saw. He exercises general supervision over the sawing of the logs, instructing the setter as to the material to be cut from each. He operates with one hand the lever which controls the movements of the carriage, and with the other the lever which directs the work of the steam nigger or log turner. He controls the log stop and loader by a foot lever. One sawyer is required for each band saw.

Band mills consist of an endless saw revolving upon an upper and a lower wheel. The wheels are usually 8 feet in diameter for the smaller saw and 9 feet for the larger, the combination of 9 and 10 foot mills occurring in but few instances. The sawing is done at a point between the two wheels. The bands used in this region have but one cutting edge, thus but one board is removed at each forward and backward movement of the carriage past the saw. The saws commonly used in California pine are 14 gauge and are swaged to cut a kerf of five-thirty-seconds inch or scant three-sixteenths inch. The

width may be either 12 or 14 inches. The length of a saw for a 9-foot band is 56 feet, and for an 8-foot band the length is 45 feet. The cost f. o. b. San Francisco is $2.25 per foot for 12-inch widths, and $3.15 per foot for 14-inch.

As the slabs and boards are sawed from the log they fall upon live rolls, consisting of iron cylinders 1 foot in diameter and 2½ or 3 feet in length, spaced 4 feet apart in two parallel series extending from each band saw to the trimmer conveyor in the rear of the mill. The rolls are rotated continuously in the direction of the rear of the mill by means of shafting and gears. An off-bearer stands behind each saw for the purpose of seeing that the boards and slabs fall on the rolls free of the saw.

The boards pass down the live rolls until they reach the edgers, where an automatic transfer removes them to the edger table. An edger is provided for each band saw. The usual type is a 60-inch gang with four or five circular saws. Two men are required at each edger, a pointer and an edgerman. The boards are fed through the edger, the saws having first been adjusted to cut off the edgings and saw the boards into the widths desired.

From the edgers the lumber and edgings pass to a double series of live rolls, about 6 feet wide and 30 feet in length, termed rear edger tables. Underneath these tables there are a number of conveyor chains working toward the side of the mill where the slash saws are located. Two or three men are stationed at the rear edger tables for shoving edgings off onto the slasher conveyor. One of these men also tends the slasher. Slabs do not go through the edgers but pass directly down the rolls and are thrown off on the slasher conveyor by the same three men. The slasher consists of from five to seven circular saws set either 3 or 4 feet apart on a shaft. The slabs and edgings pass under these saws and are cut in lengths for cordwood or lath bolts.

The rear edger tables deliver the lumber to the trimmer transfer, where another chain conveyor moves the boards to the trimmer. The trimmer consists of 10 or 11 circular saws, mounted in a row. It may be either of the underneath or overhead type and be either hand or pneumatic lift. Its function is to trim off the ends of the boards to standard lengths. After going through the trimmer the boards pass to the sorting table, where the grading and sorting is done. The crew at the trimmer consists of the trimmerman, who adjusts the saws, and two men who arrange the boards on the trimmer table. A third man is often necessary on the trimmer conveyor.

A short conveyor is located behind the slasher for the purpose of transporting the slabs and edgings to the main conveyor and refuse burner. Lath bolts and wood are commonly picked out of this conveyor, when utilized. On the lower floor of the mill is located all

the machinery for transmission of power to the sawing equipment on the mill floor. There are also various conveyors for transporting bark, pieces of slabs, and trimmings to the main refuse conveyor. A special conveyor delivers the sawdust to the boiler room for fuel.

The standard equipment for a double-band mill is six 60 inch by 16 foot boilers, capable of operation at 150 pounds steam pressure. One of these furnishes steam for the various steam appliances and the other five supply the engines. One or two engines capable of producing an aggregate of from 500 to 650 horsepower are necessary. The usual plant consists of two engines, one with about 200 horsepower and the other about 400 horsepower, or there may be one large engine of from 450 to 500 horsepower and a small one of from 100 to 150 horsepower. The engine room also contains a generator for electric light and one or more steam pumps.

A very important part of the work in a band mill is the filing of the saws. Expert labor and special equipment are required. The filing room is usually located in the garret above the mill floor. Unless accidents occur, four saws are used daily on each band mill. Usually a stock of four or five saws is kept on hand for each band. The usual filing room equipment consists of one band saw gumming and filing machine, a similar machine for circular saws, one roller for band saws, an anvil, forge, and various hand swages.

The standard crew of a double-band mill contains, in addition to the men mentioned above, an engineer and two firemen, a millwright, an oiler, one laborer tending refuse conveyor and burner, and one laborer clearing refuse on mill floor. When the mill is operating two shifts the entire crew given above is duplicated at night. The mill superintendent, two filers, and a laborer clearing refuse on the machinery floor are on duty only during the day shift. A watchman is required at night. The common practice is to work two 10-hour shifts, one during the day and one at night. When some mills operating only in the day shift wish to increase slightly the output, an extra shift of 2½ hours is worked in the evening by the day crew. This procedure is termed working a time and a quarter. If this is continued long the crew is liable to become overworked and the production suffer. This is particularly true with regard to the band sawyers, upon whose skill and watchfulness the correct manufacture of each log largely depends.

The usual crew of a double-band mill consists of 36 men for a single shift and 68 men for two shifts. The amount sawed is usually slightly greater during the day shift. The daily labor cost at a double-band mill operating two shifts is approximately $265, which, prorated over a daily output of 240,000, is about $1.10 per 1,000 for sawing. Information available indicates that the direct cost of sawing at double-band mills in this region normally varies from $1.10 to $1.20 per

1,000. At one such mill the average labor cost for a recent season was $1.17 per 1,000, divided as follows:

Sawyer	$0.218
Edgerman	.122
Trimmers	.097
Refuse crew	.137
Deckmen	.043
Engineers	.082
Fireman	.080
Filers	.089
Oilers	$0.129
Millwrights	.064
Watchmen	.021
Superintendent	.047
Miscellaneous	.044
Total	1.173

The cost of maintaining a double-band mill after it has been in use a few years is reckoned as normally averaging about 50 cents per 1,000 feet board measure, upon the basis of the material sawed. Maintenance includes sawmill supplies and sawmill repairs. A representative division is 31 cents per 1,000 for repairs and 19 cents for supplies. The supply charge may be roughly divided into the following items:

Saws	$0.06 per 1,000
Tools	.005 per 1,000
Oil and waste	.05 per 1,000
Miscellaneous	.075 per 1,000

In a few instances double-band mills are not of the twin type described above. The two bands are placed tandem, the rear one being used as a pony mill. All logs are accordingly sawed on the first band in the usual way. Small logs are, however, cut into cants which are sawed into lumber by the second band. The carriage of the smaller band is accordingly operated at a high speed. This arrangement of the saws permits a slight decrease in the mill crew, but on the other hand the daily output is generally lowered. One large operator who has had experience with both types believes this to be the most economical type of double-band mill, if properly arranged.

The mill building for a double-band mill is at least 60 feet wide and 160 feet long. For mills of heavy construction and those equipped with a gang or a resaw the standard width is 70 feet and the length ranges up to 200 feet. There are commonly two stories with an attic for a filing room. The construction material is wood. Corrugated iron is frequently used for roofing, and sometimes for siding. A steel frame is found in but one mill, the added cost being from $25,000 to $30,000. The engine room may be located in the lower story or in a small addition to the main building. The boiler room is a separate building, usually of masonry or corrugated iron construction.

The cost of a double-band mill varies somewhat with the type of construction and length of probable operation. Large timber requires heavy equipment which costs more to purchase and install.

A long operation requires more permanent construction. The cost also varies with the location, because the expense of transporting material to some sites is a considerable item. Under normal conditions the cost of the lighter double-band mills complete, exclusive of pond and yard, is from $100,000 to $110,000. The heaviest and best constructed mills cost from $130,000 to $145,000.

One such plant recently constructed cost $145,000 complete with machinery, power plant, and buildings. The cost f. o. b. San Francisco, of the equipment contained in this plant was as follows:

Boilers, about 700 horsepower	$7,000
Engine, 650 horsepower (28 by 48 inches)	6,000
Two log kickers	1,200
Two log stops and loaders	735
Log turner	1,900
Steam nigger	550
Band mill (9-foot)	2,350
Band mill (10-foot)	2,700
Two carriages	$4,980
Two edgers	2,560
Slasher (7 saws)	550
Air lift trimmer (11 saws)	1,125
Live rolls, transfers, conveyors, chains, etc	18,350
Total	50,000

In addition to this equipment, belts, saws, piping, and other miscellaneous hardware were required at a cost of about $15,000 delivered at the site. The itemized cost of a double-band mill aggregating $100,000 is approximately as given below:

Machinery, including power plant	$40,000
Miscellaneous supplies and hardware	10,000
Lumber and timbers	$9,000
Mill foundations and boiler house	7,000
Freights and delivery	10,000
Labor in construction	24,000

A machine shop of some sort is required at every double-band mill. In it are handled heavy repairs to logging and mill equipment. The cost of a well-equipped shop is about $10,000 or $12,000. The equipment consists of 2 or 3 lathes, 1 or 2 planers, 2 drills, 1 bender, 1 steel saw, and 1 cutter and threader. A blacksmith shop is maintained in connection with the machine shop and is fitted with a trip hammer, a forge, an anvil, and a complete outfit of blacksmithing tools. A typical crew comprises 3 machinists, 1 steam fitter, 1 blacksmith, and a helper.

Two sorts of refuse burners are used. Mills located in the woods usually have an open fire with a corrugated iron or masonry shield. Those situated in towns or near extensive lumber yards have steel refuse burners with brick foundations and linings. Such a burner for a double-band mill is about 70 feet high and 20 feet in diameter, and is said to cost from $6,000 to $9,000 in place.

The average output of a double-band mill is usually about 120,000 or 125,000 in a 10-hour shift for the entire sawing season. A similar average output for two shifts is 240,000 daily. During the middle of the season when everything is running nicely these average outputs will be exceeded by from 10,000 to 30,000 per day. One firm even

averages for a month or more at a time a daily output of 180,000 in a 10-hour shift. The dimensions of the material manufactured have considerable effect on the output; the more thick stock the greater the output

One method of increasing the output of a double-band mill is to add a resaw to the equipment. The mill is built somewhat wider, and the resaw is installed between the rear edger tables just aft of the edgers. The usual type of resaw is a 6-foot horizontal or vertical band. Material to be resawn is sent down the live rolls to an automatic transfer, which carries it to the feeding table of the resaw. Each plank is fed through the resaw in the direction of the front end of the mill. A third edger is placed beside the resaw for handling the resawed material. The usual mill crew is increased by 2 men feeding the resaw, 1 sawyer, 1 man at rear of resaw, 1 edgerman, and 1 man at trimmer conveyor. The average daily output is 160,000, an increase of about 35,000 because of the resaw.

A less desirable means of making a similar increase in output is the the installation of a gang saw. The gang is set upon a solid foundation midway between the band saws and the edgers. A small deck slopes from the live rolls on either side to a set of feed rolls in the center. Cants are cut from time to time by the band saws and delivered from the live rolls to the feed rolls of the gang by automatic kickers. The cants are then slowly fed through the gang by the feed rolls, thus producing a number of boards at one time. A separate series of rolls extends from the gang to the trimmer conveyor.

A gang-saw crew consists of 1 man at the feed rolls, 1 sawyer, 2 men at rear table, and 1 man on trimmer conveyor. The daily output of a double-band mill with a gang is about 160,000 feet board measure. The common type of gang saw is capable of cutting a cant 28 inches wide and 12 inches thick. The cost f. o. b. the factory is about $5,000. It produces perfectly sawed lumber, but it is impossible to saw to produce higher grades, as is done with a band saw. Thus gang saws are generally not regarded with favor in the sugar and yellow pine region where the profit is made from the upper grades. A gang saw can, however, be used to advantage upon an operation producing enough low-grade logs, suitably only for common or box lumber, to supply it all the time. Otherwise there is a tendency to run better-grade logs through it at times, which results in a loss of uppers.

A mill of an unusual type in this region, there being but two in operation, consists of a single band and a gang. The operation is in general the same as in a double-band and gang mill. The average daily output for a single shift is from 100,000 to 120,000.

Electric drive for sawmills has not been introduced as yet on an extensive scale, there being but one sugar and yellow pine mill so equipped. The power is generated in the engine room of the plant

and each piece of machinery in the mill is driven by a separate motor. The intricate machinery located on the lower floor of a mill for the transmission of power is eliminated, and one portion of the mill may be shut down for brief repairs without interfering with the rest. The installation of an electric drive makes a considerable increase in the initial cost of a mill.

The majority of the mills in the region utilize a considerable portion of the waste in slabs and edgings by making laths. A lath room is located in an addition on the side of the mill building near the slasher. At a representative double-band mill where both laths and car strips are manufactured, 2 men are required to sort material out of the conveyor at the rear of the slasher. The remainder of the crew consists of 2 men at the bolter, 2 at the saw, and 2 men bundling and jointing. The mill is equipped with separate bolters, saws, and jointers for both laths and strips. Only one product is manufactured at a time. From 180 to 200 bundles are produced daily. The demand is limited and the profit small.

Many mills have a market for fuel wood cut from slabs. Various devices, such as gang cut-offs, are used to saw the slabs and slashings into stove lengths. One progressive concern takes advantage of a chance for close utilization by resawing slabs. The larger slabs are cut in 4 and 6 foot lengths with a cut-off saw and transported by a conveyor to a resaw in the nearby planing mill. This resaw is a small horizontal band. The slab sections are resawed and edged, thus making excellent box and factory material.

The grading and sorting of the lumber is done on a sorting table which commonly extends at right angles from the mill, opposite the trimmer. This sorting table is 18 or 20 feet wide and from 120 to 160 feet in length. The lumber is carried slowly toward the outer end by means of conveyor chains or cables. The grader stands at the end near the mill and marks the grade symbol on each board with a crayon. As the boards are carried along the sorting chains they are picked up by the sorters and loaded on the proper cars. The cost of grading and sorting is about 25 cents per 1,000. At a mill producing 160,000 daily the crew consists of 1 grader and 14 sorters. The daily labor cost is $38, or 24 cents per 1,000. At a mill producing 120,000 daily the crew consists of one grader and nine sorters, at a daily labor cost of $26, or 22 cents per 1,000. The total cost of sawing, grading, and sorting at double-band mills is normally between $1.85 and $1.95 per 1,000.

SAWMILL LUMBER YARDS

Under "sawmill lumber yards" is included all handling and treatment of lumber from the time it is sorted until it is loaded on cars ready for shipment to market.

Wherever conditions are favorable, it is customary to locate the drying and shipping yard at the sawmill because of greater economy. However, this is often impossible. There are two general types of yards. In one, the lumber is distributed on elevated platforms; in the other, tracks are built at ground level.

Yards at small circular mills usually have a single track extending straight out from the mill with pile bottoms on either side. Under most conditions the necessary length is about 600 feet, and about 50 pile bottoms are required. The track may be either on the ground or on a platform raised about 10 or 12 feet. The slope should be away from the mill. Ordinarily, low four-wheeled cars are used. The cost of such a yard, exclusive of the site, is estimated to be from $600 to $800 for a ground track and from $1,000 to $1,200 for a raised platform. The larger circular mills require more yard room. This is usually secured by constructing two or more parallel tracks or platforms with piles on either side. Some operators haul the lumber out with carts and have only dirt or plank roads between the piles. Although the amount of yard stock at different mills varies with market and other conditions, the yard at a large single circular mill must ordinarily provide room for from 2½ to 3 million feet of lumber. This requires from 150 to 160 pile bottoms and 2,000 feet of trams. Accordingly, the yard cost is from $2,000 to $3,300, the latter for elevated trams.

Single-band mills have the same general layout of yards except that more space is required. A single-band mill operating one shift daily, normally requires maximum yard room for the storage of about 5 or 6 million feet of lumber. Thus from 200 to 250 pile bottoms and about 3,000 feet of trams are necessary. The average cost is placed at from $3,800 to $5,000. From one-half to three-fourths of a mile of loading spur will also be required at a cost of from $2,400 to $3,600.

There are three kinds of yards used for double-band mills in this region. The most common is the type with raised trams or platforms. These platforms are constructed in parallel series through the yard, generally at right angles to the mill. A similar platform connects the various branches to the upper floor of the mill. The platforms are constructed at a height of from 9 to 16 feet above the ground, the normal height being about 12 feet. The floor is 12 feet wide and is built of 2-inch planks. The trams are supported by 3 by 8 inch stringers and 4 by 6 inch uprights resting on 6 by 6 inch sills. About 4,000 feet of lumber is used to build each 100 feet of length.

The cost of such platforms may be computed on the basis of a cost of $18 per 1,000 for the lumber used in construction. If cars are to be used for distributing lumber, 16-pound rails must be laid on the

trams. The cost of such track, including rails, rail fastenings, and laying, is about $22 per 100 feet.

The usual yard arrangement provides for a row of lumber piles on each side of every platform. Foundations must be constructed of timbers for each pile. They contain from 400 to 500 feet of lumber apiece; and the cost of construction, including the value of the lumber, is usually about $8 each. Enough space is left between adjacent platforms to allow room for the construction of a wagon road, yard car track, or loading spur between the two series of lumber piles.

Yard tracks are commonly 36-inch gauge with 16-pound rails, and are constructed at about the following average cost per mile:

Steel and fastenings	$1,100
Ties	500
Grading	200
Laying and surfacing	300
Total	2,100

Loading spurs are standard gauge with about 35-pound rails. The cost per mile of length is reckoned as follows:

Steel and fastenings	$2,500
Ties	1,000
Grading	500
Laying and surfacing	500
Total	4,500

A yard with a storage capacity of 12,000,000 feet, at a representative double-band mill operating one shift daily, contains about 500 pile bottoms, 7,000 feet of platforms, 7,000 feet of yard track on platforms, 1 mile of loading spurs, and 1 mile of ground yard track. The cost would be reckoned as follows:

Pile bottoms	$4,000
Platforms	5,040
Platform tracks	1,540
Yard tracks	2,100
Loading spurs	4,500
Total	17,180

The cost of a yard of the platform type at a double-band mill with an annual output of from 18 to 20 million feet of lumber is usually from $16,000 to $20,000. The cost of a yard at a mill producing from 35 to 40 million feet annually would be about twice as much.

The second kind of yard is one having the tracks located on the ground. The piles are on both sides of parallel tracks in much the same manner as with platforms. The cost, computed on the same basis as above, is about $15,000. Another yard of this same type has dirt roads between the piles, upon which the lumber is dis-

tributed by horse trucks. The cost is decreased by the elimination of yard tracks.

Water systems must be installed for the protection of all yards, at a cost in addition to the above. Yard equipment, such as cars or trucks, represents a considerable additional investment. Sheds are added to most yards for storing air and kiln dried lumber.

From the sorting table lumber is distributed to the piles by means of two-wheeled lumber trucks (buggies) or low four-wheeled cars. Steel tracks are required for the cars, but the trucks can be used on plank platforms. If the yard slopes slightly away from the mill both cars and trucks may be handled by hand labor. Where the haul is long or difficult horses may be used. Apparently one of the most economical methods at large mills is to use a small gasoline or electric locomotive.

The cost of distributing lumber ready for piling averages from 20 to 25 cents per 1,000. The cost at small mills is frequently lower than at large mills, because the distance is less. At one mill cutting 20,000 daily two men are required to push the loaded lumber cars to the yard and unload them. The daily cost is $5, which is at the rate of 25 cents per 1,000. However, one of these men devotes part of his time to wheeling out slabs, so the actual cost is less. At a representative single-band mill sawing 60,000 feet in a shift of 10 hours the lumber is distributed in the yard on cars by four men, at a cost of $11 per day, or 18 cents per 1,000. A smaller single-band mill with a daily output of 50,000 maintains a crew of four men to wheel the lumber out on trucks. The wages are $10 daily, or 20 cents per 1,000. A double-band mill located at the upper end of a flume, and having a daily output of 250,000, has a crew of 20 men distributing lumber on trucks. At a daily wage of $2.50 each the cost is $50 per day, or 20 cents per 1,000.

After the lumber is distributed the next step is piling it. The boards are laid in layers, stickers 1 or 2 inches thick being placed between the layers in order to provide circulation for air in drying. Spaces are left between the various boards in each layer for the same purpose. The piles are made with the rear end lower, and when completed are roofed to shed rain. Each pile preferably contains a single grade and boards of one length only.

Piling is ordinarily done by hand, two men working together. For high piling derrick hoists operated either by a horse or by an electric motor are used to raise the boards. A third man is required in such instances. An electric piler requiring only two men is used by one company. Piling lumber is tedious work and is a job at which best results seem to be secured by contract. In fact, so much of the piling is done by this system that contract rates may be taken as standard

costs. These rates for piling up to 15 feet above the track or platform range from 35 to 40 cents per 1,000 feet board measure. At some mills the rate is 35 cents per 1,000 for ordinary piling, and 50 cents per 1,000 for piling clears, with which extra care is taken. The contract rate for piling over 15 feet above the tram is 40 cents per 1,000, upon condition that the company furnish a man and horse for the hoist. On contract work two men usually pile a little more than 20,000 feet daily, thus making very good wages. When working by the day two good men pile from 15,000 to 18,000 daily. At one single-band mill eight men pile the daily output of 60,000 at a labor cost of $20 daily, or 33 cents per 1,000. Upon the basis of the above costs the average cost of taking lumber from the mill and placing it in the piles is from 60 to 70 cents per 1,000.

When lumber is loaded from the piles directly to cars for shipment the cost is from 30 to 35 cents per 1,000, including grading. However, it is not possible to load much lumber in this manner because several different grades, which come from different piles, must be placed in one car. At one mill where the lumber is dried in the mill yard but shipped to the main line on a narrow-gauge railroad the cost of loading is about 34 cents per 1,000, including grading, and the cost of transferring to standard-gauge cars at the lower terminal is 33 cents per 1,000. Usually the lumber is taken from the pile and loaded on small yard cars. These yard cars are pushed a short distance to the loading dock where the standard-gauge cars are spotted for loading. The cost is from 20 to 25 cents for the first handling and the same for loading, plus about 10 cents per 1,000 for grading and running cars. Since some lumber is loaded by both methods in most yards, it seems proper to figure the cost of shipment of rough lumber at 50 cents per 1,000. It is customary to figure that lumber can be handled once (from piles to finishing plants, for instance) for 25 cents per 1,000.

In addition to shipment and delivery of lumber to finishing plants there is a certain amount of extra handling of lumber in the yards of all large mills. This consists in the resorting and transportation of material which has depreciated in grade, and similar work. The extent and cost of such work varies greatly.

A certain amount of supervision is necessary in any yard. At a single-band mill there is usually only a yard foreman. At a double-band mill the yard office ordinarily contains a yard foreman and a clerk, who are employed practically the year round. The cost of yard supervision is therefore about 8 or 10 cents per 1,000. There is a small additional yard cost for the maintenance of tracks and tramways. This probably does not exceed 5 cents per 1,000.

On the east slope of the Sierras the climate is so well suited to drying lumber that dry kilns are not necessary. On the west slope, however, it is the practice to run part or all of the upper grades of

yellow pine through a dry kiln on account of the danger from blue stain in air drying. A kiln 20 by 100 feet has an average daily capacity of 12,000 feet. Thus at a single-band mill the usual kiln is about 20 by 75 feet or 20 by 100 feet. Under very unfavorable drying conditions such a mill may have a pair of kilns each 20 feet wide and 70 feet long. At a double-band mill, operating two shifts, the dry-kiln plant consists of two kilns each 20 by 100 feet, if drying conditions are favorable. Under less favorable conditions the plant is often double that size.

Dry kilns may be made of masonry, concrete, wood frame, or wood crib. Masonry and concrete are said to give the best satisfaction. Wood crib is rated as being superior to wood frame construction. The cost of the equipment and fittings for a kiln 20 feet wide and 100 feet long, inside measurement, is about $1,600 f. o. b. factory. With a wood crib frame the cost of a kiln of this size in place is from $3,500 to $4,000. A kiln 20 by 70 feet with wood frame costs about $2,500 in place. A kiln of the same size costs about $10,000 if the material is concrete; and $7,000 if the material is tile. The average cost of kiln drying lumber in this region is usually from 75 to 80 cents per 1,000. The cost of handling is approximately 65 cents per 1,000.

A portion of the upper grades is usually stored in sheds if it is not shipped immediately after air or kiln drying. The construction of sufficient shed room to accommodate all upper grades would undoubtedly be an economy, because such sheds, though they involve an extra handling, do much to prevent deterioration in the quality of the lumber and insure a higher return. Care with wide and thick sugar pine lumber pays especially well. All yards in this region suffer from lumber depreciation by waste or change in grades through staining, checking, etc. The amount of this depreciation varies with yard conditions and the care in handling. It is generally greater in thick lumber than in thin lumber. Yards with unfavorable climatic and meteorological conditions suffer more heavily than those with good drying conditions. Deterioration takes place in kiln drying and surfacing, as well as in air drying. Thus shipping tallies at yards differ in amount and quality from mill tallies of lumber. Little is now known of the amount of deterioration; but studies are being undertaken to determine the amount and extent of depreciation in each grade, under different seasoning conditions and methods.

Sometimes surfaced lumber is shipped from the larger mills in order to save on freight charges. Thus, in stumpage appraisals it is necessary to add to the sawmill investment enough to cover the cost of a planing mill for this purpose, and in computing the cost of lumber an allowance must be made for this planing. In most instances the planing mill is closely connected with the box factory and it is difficult to separate the equipment. For a medium-sized

mill a double surfacer and a small band resaw are required. Power is usually furnished by a separate plant from that of the sawmill, though it may be combined with the power plant of the box factory. Planing mills cost from $4,000 to $5,000 for a sawmill of 40,000 feet capacity, from $8,000 to $10,000 for a single-band mill, and $15,000 for a double-band mill. The cost of planing is approximately $1 per 1,000. It is estimated that 30 per cent is the normal proportion of the output that is surfaced in this manner. Upon this basis the prorated cost upon the entire cut would be from 30 to 35 cents per 1,000.

Taking all the above items into consideration, the cost of yard handling at most band mills ranges from $1.65 to $2 per 1,000. A cost of $1.85 per 1,000 may be considered as normal. At smaller mills the yard work involves less detail and costs less.

Most large lumber concerns also operate box and door factories and finishing plants. These are commonly operated in connection with the shipping yards. The principal products are door cuttings, box shooks, moldings, etc., which may be considered as products obtained from the remanufacture of lumber.

TRANSPORTATION TO COMMON CARRIERS.

All sawmills located on common carrier trunk-line railroads load their lumber product for shipment directly into trunk-line cars in the shipping yard. A large proportion of the mills in the sugar and yellow pine region, not so advantageously located, must provide some means of delivering lumber to the trunk-line shipping points.

WAGON HAULS.

The simplest method of transporting lumber is to haul it on wagons with horses. It is the only means at practically all of the small circular mills. At the smallest of these the cut is sold at the mill and each rancher hauls home his purchase. Where the lumber is shipped on the nearest railroad or sold to retail yards in the nearest large town, the sawmill operator maintains a number of teams and wagons for hauling lumber.

The usual lumber outfit consists of a jerk-line team of eight horses hauling two wagons and driven by one teamster. For a 10-mile haul with a moderate amount of adverse grade the average load of lumber is 800 feet per horse. The average load for a team is therefore in the neighborhood of 6,000 feet. Upon an 8 to 10 mile haul such a team makes one round trip daily. Practically all such hauling is done on contract by the owners of the teams and wagons used. The standard contract rate for a haul of 9 or 10 miles with a small amount of adverse grade is $3 per 1,000. The contract rate for a difficult haul of 40 miles in length is $10 per 1,000. The rate for a 40-mile

haul all downgrade is about \$8 per 1,000. The rate for a haul of $3\frac{1}{2}$ miles is \$1.50 per 1,000. These charges are for air-dried lumber.

Loading and unloading is not included in these rates. The sawmill operator consequently maintains a crew in his mill yard to load the wagons, and another crew at the railroad to unload them. Many small concerns load the cars directly from the wagons. Others maintain a small yard alongside the loading spur.

TRACTION HAULS.

Lumber from a few of the larger circular mills is delivered to the railroad by means of traction engines similar to those employed in hauling logs. The trucks are much lighter, however, being merely heavy wagons in some instances. Several trucks are hauled at one time. The direct cost is considerably less than for hauling with horses, but the investment involved is much greater and there is much more risk of delay through breakdowns and inclement weather. On the whole the method serves very well for mills with a moderate output where road conditions are satisfactory. With a large output and consequent heavy traffic it is practically impossible to keep the road in satisfactory condition.

LUMBER RAILROADS.

The most satisfactory method of delivering lumber from the mill to the trunk railroad is by means of a lumber-carrying railroad. All new mills employ this means of transportation wherever the amount of timber is sufficient to justify the investment. Whenever one of the trunk roads can not be induced to build a branch line it is necessary for the lumber operator to construct the road.

Operators prefer to build and operate such lines as private roads in order to avoid certain State regulations as to common carriers. However, in order to secure rights of way it is frequently necessary to make them common carriers. In practically all cases standard gauge is preferred because foreign cars can then be loaded at the mill. In fact, the only circumstance under which a narrow gauge can be considered is when the lumber-drying yard can not be located at the sawmill. Even then the necessity of transferring all supplies and equipment to narrow-gauge cars before delivery at the mill makes the desirability of a narrow gauge doubtful.

The layout and cost of construction of lumber roads are about the same as for logging railroads. Lumber railroads are generally of longer life than logging roads, and the construction can therefore be more permanent. The use of rod engines with heavy trains is usually provided for in laying out the road. In consequence, the maximum grades are 3 or 4 per cent for empty trains and 1 or 2 per cent for loaded trains. Curves are ordinarily not over from 16 to 20 degrees.

The construction materials used are the same as for logging roads, except that the steel is usually 56 or 60 pounds.

The locomotives engaged on lumber hauls vary from 35 to 90 tons in weight. The smaller engines are employed on short, easy hauls. An engine of from 70 to 75 tons in weight is commonly the most satisfactory for the longer lumber hauls. Where the cars are owned by the lumber operator light flat cars are employed. Foreign cars are always used whenever possible.

One 75-ton locomotive and crew will handle the output of a double-band mill for distances up to 30 miles on roads with moderate grades. Two trips are made daily on a 15-mile run and one trip daily on a 30-mile run. A crew consists of a conductor, engineer, fireman, and one or two brakemen. Definite cost figures on the operation of private lumber railroads are not at hand, but it is estimated that dry lumber can be transported for from 50 to 75 cents per 1,000 for hauls of from 10 to 15 miles.

Whenever it is necessary for the railroad to be a common carrier, a separate company owned by the lumber company stockholders is usually formed to operate it. The rates of common carrier railroads are subject to revision and approval by the State Railroad Commission. They are theoretically equal to the proportionate cost of operation plus a reasonable profit on the investment. The local rates upon a number of primarily lumber-carrying railroads follow:

Name of road.	Points.	Mileage.	Rate per 2,000 pounds.
McCloud River Railroad	McCloud to Sisson	17	$2.25
Sugar Pine Railroad	Lyons Dam to Sonora	23	1.35
Boca & Loyalton Railroad	Loyalton to Boca	26	1.50
Sierra Railway	Tuolumne to Oakdale	57	1.60
Butte County Railroad	Sterling City to Barber	30	1.65
San Joaquin & Eastern Railroad	White Pine to El Prado	45	2.25

These local rates are used in combination with trunk-line rates for most California shipments. Points on some of these lines take coast group rates in transcontinental shipments. Air-dried pine lumber has a shipping weight of from 2,500 to 2,700 pounds per 1,000 feet board measure.

LUMBER INCLINES.

Where the sawmill is located within a short distance of a trunk-line railroad but at a considerably higher elevation, an incline is frequently the best and most economical method of delivering the lumber at the loading spur. There are several such inclines in operation, as well as one or two where the lumber is hauled up instead of lowered. An incline located in the central Sierras, and in general typical of them all, is described below.

The upper end of the incline is near the mill and the lower terminus is on a trunk-line railroad. Its length is 4,200 feet and the difference in elevation is 1,500 feet, making an average grade of 38.5 per cent. The maximum grade is 72 per cent on a stretch of 125 feet. The alignment of the track involves three tangents, varying about 5 degrees in direction, joined by two 10-degree curves. The grade at the curves is flattened out to about 10 per cent. The track is narrow gauge with 45-pound rails and 6 by 8 inch by 6 feet redwood ties, dirt ballasted in the usual manner, no other provision being necessary to prevent the track creeping downhill. The initial cost of the construction of the track was between $6,000 and $7,000. The expense of delivering the ties and rail on the ground was very high.

The cars are lowered by a 1-inch cable, supported by 33 ground rollers and three upright rollers. The cable is controlled by a large wooden drum 11 feet in diameter and 14 feet in width, located in a building at the top of the incline. This drum is equipped with a brake wheel 16 feet in diameter and the load is let down by a hand brake. A 14 by 20 inch twin cylinder hoisting engine from 150 to 200 horsepower operates the drum in hauling up the empty car. This equipment has sufficient power to haul up an ordinary sawmill boiler. A 60 inch by 16 foot boiler is required to supply the engine with steam. The cost of the power plant was about $5,000.

The lumber is lowered on 21-foot narrow-gauge flat cars, one car at a trip. The average load per car is about 3,000 feet, and a round trip is made in one-half hour, including switching. The usual average daily output is 40,000 and the normal capacity is 60,000 feet board measure. The crew consists of an engineer, fireman, and brakeman. The cost of operation is calculated at from 35 to 40 cents per 1,000.

LUMBER FLUMES.

Another way of transporting lumber from inaccessible sawmill sites to trunk railroads is by means of flumes. These can be built at a lower cost per mile than railroads and heavier grades may be descended, thus reducing the mileage. The initial cost is at least from 60 to 75 per cent less than for a railroad. Another advantage is that the water used in the flume can in most instances be disposed of for irrigation purposes at the lower end.

The direct cost of fluming lumber is low, but the cost of maintaining the flume is very heavy. The principal disadvantage is that all equipment and supplies used in the logging and sawmill operation must be freighted in with teams for distances of from 40 to 50 miles. The expense of such freighting ranges from $15 to $20 per ton. Other disadvantages are the wear of the lumber in the flume and the difficulty of shipping wide boards. For these and

other reasons it is improbable that any more lumber-carrying flumes will be constructed in California, except in instances where a railroad or incline is clearly impracticable.

There are several flumes now in successful operation in California, though the number in use is gradually decreasing. The longest ones are located in the southern Sierras, where longer and more expensive railroads are required to reach merchantable timber than in the northern part of the State. The lengths of the three flumes in the southern Sierras are respectively 42, 56, and 60 miles. On the other hand, one flume located in northern California is only 4½ miles in length.

These flumes consist of a V-shaped box with sides 32 inches wide in the mountains and 48 inches wide where the grade is low and the water sluggish. The angle formed by the sides of the flume is a right angle, and the width across the top is 46 inches where the sides are 32 inches wide. The flume box is supported at distances of either 8 or 16 feet by bents composed of 4 by 6 inch or 6 by 6 inch fir timbers. In the original construction bents were placed at 16-foot intervals, but it has been found advisable to place supports every 8 feet for low trestles. Higher trestles are still constructed with 16-foot bents, but heavier timber and sway and stringer braces are used. Two 4 by 6 inch stringers are supported by the bents. Upon the stringers at intervals of 4 feet are placed the braces which hold the flume box in an upright position.

The cost of constructing flumes varies with the difficulty of preparing the ground for foundations and the average height of the bents; with lumber at $12 per 1,000 it ranges from $20 to $25 per 1,000 board feet, the higher cost being where the average height of the flume is least. The lowest recorded cost is for two flumes in northern California, approximately $4,000 per mile. In the southern Sierras the natural conditions affecting construction are more difficult, and the average cost of construction is about $5,000 per mile. The most expensive flume in that locality is reported to have cost $6,000 per mile. The average amount of material is from 225,000 to 275,000 feet per mile. Farther north the average is not over 175,000 feet.

The maximum grade allowable is about 25 per cent for short pitches. Normally the grade is kept down to between 5 and 10 per cent, with 12 per cent as a maximum. In the San Joaquin Valley the grade is very low. One flume in which the lumber is shipped in bundles has approximately 13 miles on the lower end with a grade of only 0.13 per cent. Another in which the lumber is shipped loose has a similar length of slack water with a grade of 0.26 per cent. The maximum curve used is about 20 degrees. The volume of water required to operate a flume varies from 25 to 35 second-feet.

Lumber is shipped in flumes either loose or in bundles. Shipment in bundles is the most common, and is adapted to flumes having lower grades. The loss of lumber is less than for the other method and fewer herders are required. However, the cost of bundling is considerable and the clamps must be hauled back to the upper end of the flume at a cost of about 1 cent per pound. In either method the lumber is graded and sorted roughly and distributed to the drying piles and shipping skids, which are located along a number of branches feeding into the main flume. In shipping loose in long flumes it is necessary to kiln dry boards from yellow pine and white fir butts and air dry thick or heavy sugar pine boards. This involves a considerable cost for handling in the mill yard and kiln, and loss occurs through stain in air drying. Up to the present the same practice has been customary in fluming in bundles. Recently, however, one company has developed a method of mixing light and heavy lumber in each bundle. All lumber may thus be shipped immediately after sawing, and air and kiln drying at the mill is practically eliminated.

In shipping loose, the lumber is distributed to various shipping skids. The boards are then thrown one at a time into the flume by the shippers.

In bundle shipping the boards are made up in bundles from 10 to 13 inches thick, bound at each end by iron clamps and wooden wedges. The bundles are then thrown into the flume and trains of five or six are fastened together with short rope loops. A crew of 27 men, three men working at each of nine skids, may prepare the bundles for a shipment of about 210,000 feet daily. The remainder of the shipping crew is made up of three men tying the bundles together, one man straightening clamps, one man distributing clamps, one man distributing wedges, and one foreman.

As the bundles pass down the flume they are cared for by herders who prevent jams and watch for flume breaks. On a typical operation the flume is divided into six-mile sections and two herders are assigned to each. With two extra herders on the last half mile the herding crew consists of 20 men and a foreman. At the lower end the bundles are dumped by hand from slack water by a crew of five men. The clamps are then loosened and the boards distributed and handled in the yard in the same manner as if the yard were located at the sawmill.

The cost of flume maintenance is considerable. On the long flumes a repair crew is engaged all winter, and approximately a million feet of lumber is used annually in repairs. The average cost is calculated at 80 cents per 1,000 for two flumes 56 and 60 miles in length and 65 cents per 1,000 for one 42 miles in length. Exclusive of depreciation the average cost of fluming lumber in these long

flumes ranges from \$1.75 to \$1.90 per 1,000. The cost of fluming in short flumes with steep grades all the way is much less. In one such flume $4\frac{1}{2}$ miles in length the lumber is shipped right from the trimmer without drying or sorting. One man is required to ship a daily output of from 60,000 to 70,000 feet. Only two herders are required, but five men are needed at the lower end to take the lumber out of the flume. The direct cost of fluming is thus about 35 cents per 1,000, and the average cost of maintenance is calculated at from 10 to 15 cents per 1,000 on a yearly output of 9,000,000 feet board measure.

PART IV. GENERAL COST FACTORS.

OVERHEAD CHARGES.

Overhead charges include all current expenses which are not directly chargeable to any particular step in the operation; that is, expenses which apply to the entire operation. This is not strictly true of certain items such as taxes and insurance, for the lump sums in which they are paid can be divided into proportionate shares for each part of the operation. Such is not the common procedure, however, and need not be attempted in ordinary calculations of operating cost. Overhead charges are ordinarily computed upon the basis of each 1,000 feet of lumber shipped and may then be applied to each 1,000 feet log scale.

Cruising and layout of logging operations are the first items of overhead cost met with. In private operations cruising is usually done at the time of purchase and may be considered as an additional cost of stumpage. Most of the layout of operations is covered by general superintendence, woods supervision, and engineering.

The cost of protecting the timber from fire is a charge for carrying stumpage rather than for logging. A considerable proportion of the fire fighting done by private operators is, however, for the purpose of protecting chutes, cables, trestles, camps, and the like, and the cost of this part of the fire protection work should be added to the logging cost. National Forest sale contracts require each purchaser to use his employees in fighting fires within a certain defined region. The cost of this work may be properly considered as an extra cost of logging.

TAXES.

Taxes on standing timber are frequently considered by lumbermen as an operating cost; but they are logically a cost of carrying stumpage, and consequently do not enter into the cost of operating. The annual tax rates in the various timber counties vary from \$1.64 to \$2.60 per \$100 of valuation. The average rate is from \$1.95 to \$2.05. Lumber plants are generally assessed at about 30 or 40 per cent of

the value. The lumber on hand in the yard at the time of assessment is valued in about the same way. Assessments are made in April, however, when the lumber stock is generally at its lowest ebb.

INSURANCE.

Lumber operators should carry both fire and liability insurance. Practically all except the small mills carry fire insurance. Most of these carry their own risk because they can not comply with the requirements of fire insurance companies without making an impossible increase in their investment.

Steam sawmills and lumber in yards at steam sawmills may be insured up to about 90 per cent of the actual value. To get a rate for a mill the procedure is to take the standard rate and make certain specified additions to it and deductions from it for designated defects in the plant or for designated protective measures. The standard rate for pine sawmills in California is $3 per $100 of insured value. An addition of $1 is made if box factory, planing mill, or boilers are located in the same or immediately adjacent buildings. On the other hand a deduction of from 50 cents to $1 is made for a good fire-protection system. As a rule the rate for normally well equipped and protected mills with power plant in a detached masonry or corrugated iron building is about $3 per hundred. For small mills in the woods which are safe enough to insure, the rate is about $5 per hundred. For especially well built mills with automatic fire sprinkler systems the rate may be as low as $2 per hundred. These are the rates established by the Board of Fire Underwriters of the Pacific Coast.

The standard rates upon lumber piled in mill yards exposed to no unusual danger are as follows:

Distance from mill.	Rate per hnndred.
250 feet	$2.00
200 feet	2.25
150 feet	2.50
100 feet	3.00
No clear space	3.50

All employees of lumbering companies come under the provisions of the California Workmen's Compensation Act, which provides certain compulsory payments in the case of injury or death of an employee. Operators usually do not wish to assume this risk and prefer to carry liability insurance. This insurance may be placed with any insurance company, provided claims are paid as directed by the State Industrial Accident Commission; or the employer may insure under the State Compensation Insurance Fund. The rates

for State and private insurance are the same and are fixed in certain amounts per each $100 paid out in wages. The schedule of rates for State insurance in 1914 was as follows:

Box manufacturers	$2.96
Lath manufacturers	4.81
Lumber yards (commercial)	2.40
Lumber yards (at sawmills)	4.81
Planing and molding mills	3.42
Sawmills	4.81
Logging	4.16
Logging railroads (operation)	11.20
Logging railroads (maintenance and construction)	4.16
Clerical force	.21

The average rate varies in different operations on account of the difference in the number of men employed in the various activities, but for a normal lumbering operation in sugar and yellow pine timber, sawmill included, it is about 4½ per cent of the pay roll. Eliminating labor hired on contract in the lumber yard, the normal wages involved in the production of a thousand feet of lumber amount to about $7. At a rate of 4½ per cent the cost for liability insurance amounts to 32 cents per 1,000. The State Compensation Insurance Fund returned 15 per cent of the premiums to policy holders in 1914.

SELLING.

The cost of selling includes all direct costs of disposing of lumber which have not been deducted from the net price of lumber f. o. b. the mill. The cost of lumber selling agencies and commissions are generally so deducted. However, most large firms have a salesman who travels for the purpose of selling lumber. For the smaller mills this selling may be done by some member of the office force who devotes but part of his time to it. At large double-band mills a sales manager is maintained the year round.

OFFICE AND GENERAL EXPENSES.

Office and general expenses include all clerical help, stationery, upkeep of office buildings, dues, and any other miscellaneous expenditures necessary in the conduct of the business.

SUPERINTENDENCE.

A lumber company with an annual output of, say, 36 million may require a manager and an assistant manager. The manager is usually an official of the company. The combined salaries and expenses are approximately $12,000, but about 20 per cent of this superintendence may be assumed as chargeable to box factories and finishing plants. Thus, in such a case the cost of superintendence is $9,600 per annum, or 27 cents per 1,000 feet. The cost of superintendence is in about the same ratio in the case of smaller operations.

One manager is required for a double-band mill producting about 20 million annually. The manager at a single-band mill operating one shift frequently directly superintends both woods and mill. A proportionate decrease is made in the office force in each instance.

SUMMARY.

To sum up: the cost of selling, general office work, and superintendance at band mill or large circular mill operations is normally from 55 to 70 cents per 1,000, and the total of overhead charges is from \$1.25 to \$1.40 per 1,000.

At small circular mills, superintendence, office work, and selling are covered by the salary of the operator. Such mills are commonly one-man concerns; and since the owner devotes all his time to the operation he should have a salary as well as a profit on the investment. A mill of 20,000 daily output markets about 3,000,000 feet per annum. At a salary of \$1,200 for the operator the cost of superintendence is 40 cents per 1,000.

DEPRECIATION.

All improvements and equipment used in lumbering depreciate in value, and sufficient money must be taken from the business during its course to form a sinking fund to cover this depreciation. The amount of depreciation is measured by the difference between the initial cost and the salvage or residual value at the end of the operation. The common method of figuring depreciation against a body of timber is to determine the total depreciation involved in its exploitation and by prorating this total over the stand to obtain a figure per 1,000 feet. The depreciation per 1,000 may then be applied to the annual cut to determine how large an annual sinking fund is necessary.

Railroads and sawmills which can be used for additional timber have a residual value at the end of the operation much greater than the salvage value. Railroads adapted to a continuous profitable common carrier business may have a residual value practically as large as the initial cost. Improvements and equipment which can not be used any further have only a salvage or wrecking value. Tools, cables, and similar equipment are worn out and must be replaced at frequent intervals, so that they rarely have even a wrecking value. Horse and donkey chutes have no salvage value, except when the material can be utilized as saw logs or made into railroad ties.

The wrecking value of logging railroads which can not be used in place for other purposes is the sale value of the rails for relaying. The rails commonly have a life of from 15 to 20 years; the former where they are lifted and relaid every season, and the latter for more

permanent use. Of course, where rails are lifted and relaid often, there is a considerable current loss through breakage and kinking. Geared locomotives, with proper maintenance and repairs, are good for about 20 years service. During that period the boilers must be replaced once. A rod engine should, under similar circumstances, have a slightly longer life, say about 25 years. Cars, either skeleton or flat, have very little salvage value after being used five years. In operations of from 15 to 20 years in length it is generally necessary to figure that the log cars will be renewed at least once.

The sale value of second-hand logging donkeys and similar equipment is very low. In first-class condition they will bring only about 30 per cent of the original factory price, and after five or six years' use donkey engines can no longer be put in first-class condition. The wrecking value is even less. Logging donkeys are ordinarily good for about 9 or 10 years' service. In some instances they may be used as long as 12 years, but if not worn out in 10 years they are at least obsolete in type.

The wrecking value of sawmills is likewise comparatively small. It is confined to the salvage value of the sawmill, planing mill, and dry kiln equipment. The lumber used in the buildings may have a small value in excess of the cost of removing it if the period of use is not too long. Depreciation commonly ranges from $1 to $1.50 per 1,000 feet board measure, depending upon the amount of timber and the extent of the necessary construction.

SUMMARY OF THE COSTS OF TYPICAL OPERATIONS.

A more comprehensive idea of the cost of lumber production may be gained from cost summaries of typical operations of three kinds; namely, a small horse-logging operation, a medium sized circular mill operation, and a large band mill operation. The cost summaries given below are made on the basis of operations of average efficiency, in much the same manner as calculations of operating costs are prepared in appraisals of National Forest stumpage, and are checked by the actual costs of various going lumber companies. The costs of any particular operation may of course differ from these summaries. Costs are in each instance on the basis of lumber shipping tally.

SMALL MILL SUPPLIED BY HORSE LOGGING.

Operating costs:	
Logging—	Per 1,000 feet
Felling, limbing and bucking	$0.75
Horse skidding and swamping	1.20
Horse chute hauling	1.40
Chute construction	.50

Operating costs—Continued.

	Per 1,000 feet.	
Sawmill and yard—		
Sawing	$1.75	
Mill maintenance	.35	
Sorting	.25	
Handling and piling	.60	
Loading	.25	
Transportation—Wagon haul	2.50	
General expense—		
Supervision and office	.70	
Taxes and insurance	.45	
		$10.70
To this should be added an average allowance for depreciation of, say		.80
Total cost		11.50

Mills of this class are usually situated close to the timber and at some distance from either the local market or a common-carrier railroad. In addition, they are often semiportable in character and are moved from time to time in order to be near the timber. Consequently, the logging costs are low, but the cost of lumber transportation is high. In the example above the length of the wagon haul is considered as about 7 miles. No allowance is made for surfacing, as the lumber is usually disposed of rough. Very little expense is necessary for selling because the lumber is generally sold to local users or to some larger producer or box-shook manufacturer.

SINGLE CIRCULAR MILL OPERATION.

Operating costs:

	Per 1,000 feet.	
Logging—		
Felling, limbing, and bucking	$0.70	
Donkey yarding	1.90	
Loading	.30	
Hauling on trucks	2.20	
Road construction	.20	
Sawmill and yard—		
Sawing	1.70	
Mill maintenance	.35	
Sorting	.25	
Piling and handling	.80	
Surfacing	.30	
Loading	.50	
General expense—		
Superintendence and office (including mill and woods supervision)	.55	
Selling	.20	
Taxes and insurance	.50	
		$10.45
Depreciation—Average		.95
Total cost		11.40

In this example the mill is situated on a common carrier. If it were not, there would be an additional cost for hauling lumber to the railroad. Since the mill is at some distance from the timber, a rather high charge is involved in truck hauling with horses or a traction engine. In an operation of this type more care and work in the yard is necessary than in smaller operations. A planer is usually operated in connection with the mill and a portion of the cut surfaced before sale. Loading on cars is a more expensive operation than loading on wagons for hauling.

LARGE BAND MILL OPERATION.

	Per 1,000 feet.	
Operating costs:		
Logging—		
Felling	$0.22	
Bucking	.08	
Limbing	.35	
Yarding labor, etc	1.58	
Yarding maintenance	.22	
Cables	.20	
Loading	.25	
Railroad operation	.50	
Railroad maintenance	.75	
Unloading	.03	
Railroad construction	.80	
Woods supervision	.22	
		$5.20
Sawmill—		
Pond	.07	
Sawing	1.15	
Sawmill supplies	.18	
Sawmill maintenance	.32	
Sawmill supervision	.05	
Sorting	.25	
		2.02
Sawmill yard—		
Distributing	.25	
Piling	.40	
Surfacing	.35	
Kilning	.30	
Loading	.50	
Supervision and upkeep	.15	
		1.95
General expense (overhead)—		
Taxes and fire insurance	.40	
Liability insurance	.35	
Selling	.25	
Superintendence and office	.40	
		1.40
Depreciation—Average		1.10
Total cost		11.67

The above list of costs does not take into account any finishing or remanufacture of lumber other than surfacing for shipment. By taking greater care of its lumber and paying more attention to selling, a large mill generally sells its product more advantageously than a small one. Since the costs at large mills vary considerably throughout the California pine region, those given above may be considered as somewhat ideal for a mill located on a common carrier and with a logging road of moderate length. Inspection of operating-cost records shows that, exclusive of profit, interest, and stumpage, the bulk of the lumber produced at large mills in this region is placed on cars at common-carrier railroad points, rough or surfaced for shipping, at from \$11.50 to \$12.50 per 1,000 feet. Mills with flumes or branch-line lumber roads, severe logging conditions, or inefficient plants may have to pay more.

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